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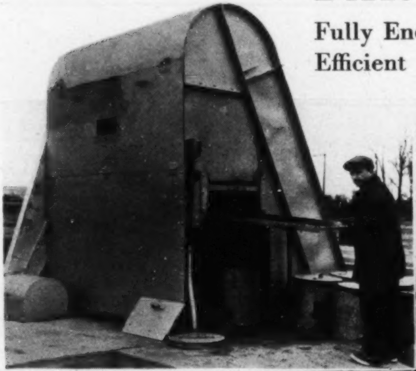

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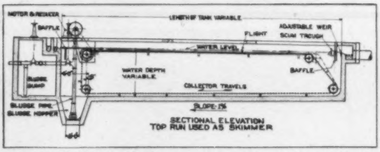
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P.W.A. JOB DOCKET 1748

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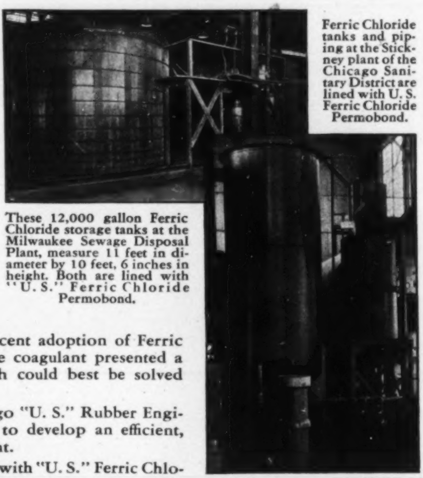

Ferric Chloride tanks and piping at the Stickney plant of the Chicago Sanitary District are lined with U. S. Ferric Chloride Permobond.

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Sewage Research

BULKING OF ACTIVATED SLUDGE

II. On the Causative Organisms

By Dr. Jan Smit

Lecturer on Microbiology, University of Amsterdam

In my first paper on this subject[1] stress was laid on the fact that, although the presence of considerable amounts of sugar is certain to cause the phenomenon of bulking, the amount of sugar-like substances even in strong sewage is so small that this substance may in all probability be excluded as the direct cause of the phenomenon.

Are there other causative factors? According to the discussion following the paper of W. Clifford and M. E. D. Windridge[2] very little seems to be known with certainty. Clifford's view, that no biological change but only the concentration of sludge is responsible for unsatisfactory settling properties, evidently applies to normal, healthy sludge (see Fig. 3 of my first paper) but does not account for the state of bulking in diseased sludge caused by the development of threadlike organisms. It seems evident that, in Clifford's studies of normal sludge, deficiency of oxygen may have had a certain influence on the critical amount of sludge, above which settlement is impaired; on the contrary, the influence of oxygen on the real bulking phenomenon is still a matter of controversy amongst different workers. A recent study by Fr. Schmiedt[3] stresses the detrimental influence of a low temperature of the diffused air and hydrogen sulphide in the sewage. It is surprising to find that the author denies the deleterious effect of sugar, stated by so many investigators.

Considering that sugar and sugar-like substances are broken down almost completely to acid products, an extensive investigation was started on the influence of various organic acids and their salts upon the sludge. It was proved that the latter were decomposed rapidly in quantities of 200 p.p.m., as were the acids themselves, provided their original concentration did now lower pH to 4.5 to 5.0. Above this pH value the acidity was changed into an alkaline reaction by a few hours' aeration. Otherwise, starting at 4.5 or lower, pH remained low and the sludge deteriorated quickly. But in both cases bulking did not occur and a slightly accelerated increase in the volume of sludge was the only phenomenon observed. Experiments with hydrochloric acid gave similar results, the amount sufficient to bring pH down to 5 being the limit of the digestible quantity. With greater acidity the sludge decreased in bulk and seemed to be digested. Its activity was also lowered, but bulking did not occur.

Repeating the experiments of Schmiedt with hydrogen sulphide, I obtained completely opposite results. For, whereas he reported a deleterious effect (bulking) due to 0.3–0.5 p.p.m. of H_2S, my experiments showed that the uninterrupted addition of 5 and even 10 p.p.m. (as Na_2S) during several weeks was in no way harmful and that these amounts were oxidized rapidly without causing bulking. A dark color of the sludge and a somewhat increased turbidity of the effluent were the only visible results.

In order to get a little further into the real cause of the phenomenon it seemed worth while to isolate the threadlike organisms present in bulking sludge and to try to study the conditions of their growth. Ruchhoft and Watkins[4] were the first to succeed in cultivating an organism which in pure culture closely resembled the threads present in bulking sludge. The convincing proof, i.e., that development of the threads is able and sufficient to cause the sludge-disease (doubtless an extremely difficult experiment), was not undertaken by them.

EXPERIMENTAL

Working along the lines of Ruchhoft and Watkins' methods (*l.c.*, p. 53) one is struck by the fact that, on the agar plates recommended by them, very large numbers of bacteria colonies, moulds and oöspora-species develop, but that organisms of a macroscopical appearance as described by Ruchhoft and Watkins are not found at first sight. Only very careful microscopical observation sometimes reveals the presence of very small colonies, in which the use of the low power already shows the threadlike structure (Fig. 1). Better results were obtained by plating the sludge on sewage-agar, containing a small amount (1/20 to 1/50 per cent) of glucose and peptone. Frequent re-plating is needed to free the threads from bacteria attached to them. A pure culture, thus obtained, shows grayish, flat colonies of a diameter of 1 to 1.5 m.m. (Fig. 2). Transplantation of such a colony into filtered sewage, to which 0.1 per cent of glucose and peptone are added, leads to a rather rapid development of a white floc closely resembling cotton-wool, whereas the liquid is left perfectly clear (if not, development of bacteria is indicated). Vigorous shaking of the flask causes disintegration of the floc, which after one-half hour again forms and settles from a clear liquid. Microscopical observation shows a conglomeration of thin threads (1–1.2 micra) (Fig. 3). Under the high power a stained preparation

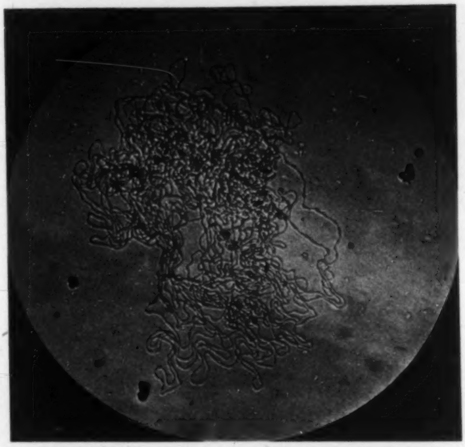

FIG. 1. Filamentous colony on sewage agar. Magn. 120.

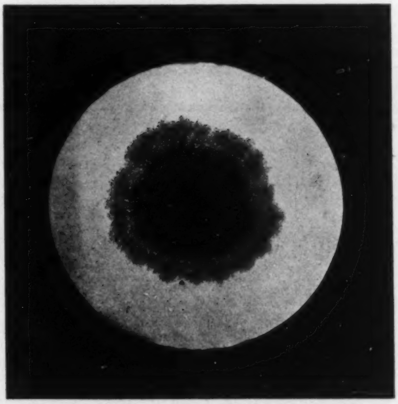

FIG. 2. Full grown colony on sewage agar. Magn. 21.

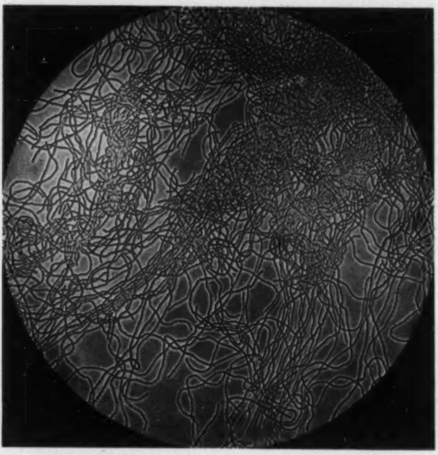

FIG. 3. Pure culture in diluted sewage with 0.1 per cent glucose. Magn. 200.

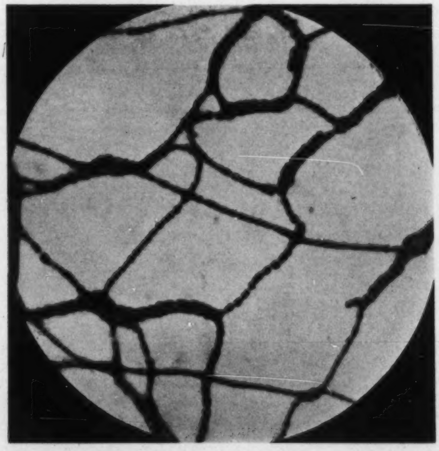

FIG. 4. The same as Fig. 3. Stained preparation (methylene blue). Magn. 1500.

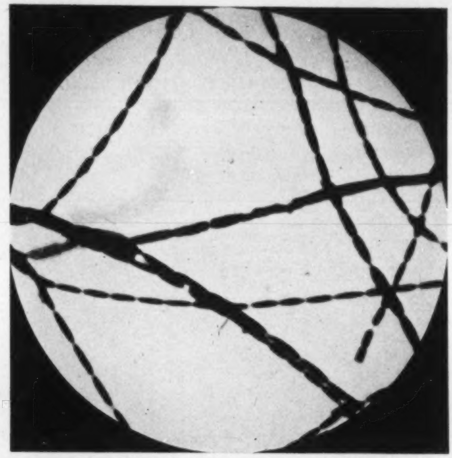

Fig. 5. Stained preparation of threads in bulking sludge. Magn. 1500.

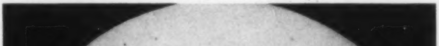

Fig. 6. Typical field, where short-fragmented thread changes into sausage-form. Magn. 1500.

(Fig. 4) closely resembles Ruchhoft and Watkins' organisms. When the stained filaments are compared with stained preparations of bulking sludge, one is struck by the variety in shape of filaments in the sludge. Besides the threads of Fig. 4, broken into short fragments, the great majority of filaments resemble the much longer ones of Fig. 5, similar to chains of sausages. But on close observation many fields were found where the older parts of the thread were like Fig. 4, gradually lengthening into the longer fragments at the youngest ends of the threads (Fig. 6), thus convincing us of their identity. In our pure cultures, however, only short-fragmented threads developed. Even in these cultures, however, the shape and size of the organism are not constant, but change with nutrition. Increasing the concentration of peptone to 1 per cent changes the filaments to the form shown in Fig. 7, with threads of nearly double the diameter and with a large number of knots, apparently caused by thickening and shrivelling of the threads. On transplanting into the more dilute solution the thin forms reappear. Development of diluted maltwort (2° Ba.) is fairly good, especially when calcium carbonate is added, which maintains the acidity at a low level. Growth on ordinary agar is rather poor; much better, when 5 per cent of defibrinated blood is added. Nitrogen as ammonium salts, nitrates, uric acid and urea (in the presence of glucose) has proved un-

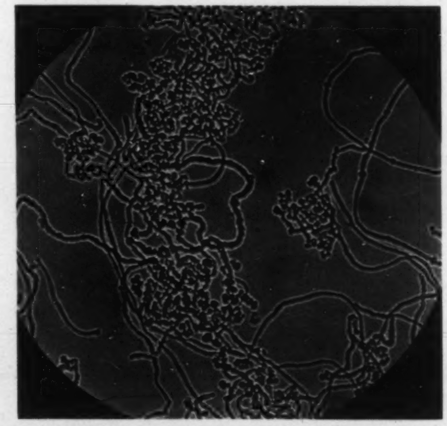

FIG. 7. Thickened growth in concentrated solution of peptone and glucose. Magn. 300.

suitable. Amino acids such as glycocoll and tyrosine allowed a slow growth. In fact the requirements of nitrogen seem to be slight, development on agar made with tap water containing 0.1 per cent glucose being fairly satisfactory. My investigations are in agreement with Ruchhoft and Watkins', in which they claim optimum growth at 20 to 25° C. and pH between 6 and 8. The thermal deathpoint lies near 60° C. (pH 7), which kills the organism if applied for more than 5 minutes.

The utilisation of carbohydrates was of special interest. Having learned that a concentration of 0.1 per cent glucose in a 1.0 per cent solution of peptone with 1.0 per cent calcium carbonate afforded optimal growth, other carbohydrates were investigated in the same manner. Growth occurred with glucose, levulose, lactose, saccharose, maltose, galactose, mannitol and salicin; glycerol and arabinose were unsuitable.

The products of sugar-metabolism were established in 1 liter of a solution of 1 per cent peptone, 0.1 per cent glucose and an excess of calcium carbonate. After a few days all sugar proved to be fermented. On distillation, after complete neutralization, a small amount of ethyl alcohol was found. Acid distillation (Duclaux method) yielded a large amount (nearly 20 per cent of the fermented sugar) of pure acetic acid. Among other products lactic acid was recovered. Quantitative estimations (offering many difficulties because of the fact that metabolism stops when only a few tenths of a per cent of sugar are split) are under way.

The behaviour of the organism toward oxygen is somewhat peculiar. While normal growth occurs on the surface of agar plates at full atmospheric pressure, it is not much less in a stoppered bottle, completely filled, with nearly complete exclusion of air. Special experiments showed that aeration during incubation resulted in a marked retardation of development. In view of the fact that bulking of activated sludge develops under full aeration of the liquid, and that excessive amounts of air neither prevent nor cure the disease, this behaviour is rather astonishing, and seems to indicate that in sewage the oxygen is unable to create conditions of full aeration, whatever the amount of air may be. This might explain in part any beneficial effect of reaeration of sludge, if the liquid has lost most of its impurities, so that the oxygen may have a stronger effect on the solids.

The identification of our organism has offered many unforeseen difficulties. Former investigators have called it *Sphaerotilus*, without sufficient identification, or quote the opinion of another investigator. It must be admitted that the genus is not very clearly described, and that only one species, *Sphaer. natans* (Kützing), forms the basis of these descriptions. From those descriptions given by Kützing, Kolkwitz,[5] Trommsdorf,[6] Zikes,[7] Naumann[8, 9] and in Bergey's Manual one would conclude that *Sphaerotilus* forms unbranched threads of 2 to 3 micra diameter, very rarely showing pseudo-dichotomy and consisting of rod-shaped or oval cells lying within a sheath difficult to see in stained preparations. Multiplication occurs by non-motile or motile, in most cases monotrich, conidia.

Ruchhoft and Watkins have already expressed their doubt as to the suitability of this description to their organism, and I can fully confirm their view. The diameter of the threads is only 1.2 to 1.5 micra, pseudo-dichotomy is *never* seen, nor have swarming cells ever been observed. The existence of a sheath is a matter of considerable uncertainty, because it is completely invisible in water-preparations and it refuses to take any colour, no matter how applied. When fixed in India ink the threads show the structure of Fig. 8, without the faintest indication of a sheath, though the individual cells are not everywhere placed closely end to end. But here, as in the stained preparations, the fact that on many spots there seems to be an empty space between the cells is convincing proof that they are held together by a sort of common envelope, which may be called a sheath, although there seems to be no means of making it visible. This coincides with the description of *Sphaerotilus* cited above.

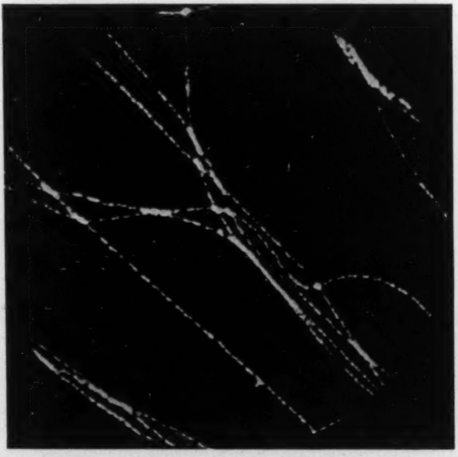

FIG. 8. Preparation in India ink. Magn. 1500.

A point of considerable difference with *Sphaerotilus*, as found in nature, seems to lie in the manner of growth. As stated above, our organism develops in a liquid medium like a piece of free-swimming cotton-wool in a perfectly clear environment, while *Sphaerotilus* in natural waters is invariably found attached to solid materials such as submerged branches and leaves. If such material is taken out and brought into a bottle with ordinary tap water, to which a few drops of broth are added, one may succeed in seeing it growing, if the liquid is renewed frequently (twice a day at least). If the liquid is not renewed, development of bacteria and algae will be found to suppress *Sphaerotilus* in a few days.* But this growth of *Sphaerotilus* invariably occurs on the glass wall, which in time will be covered by a whitish coating. *Never* will freely swimming flocs be found in the liquid. On the contrary, when our pure cultures isolated from activated sludge are treated in the same way, the developing threads never attach to the wall of the flask, but again form free swimming flocs. In addition, the cultures from river water have a very distinct sheath, visible without any coloration (Fig. 9), still better in a stained preparation (Fig. 10.) In all

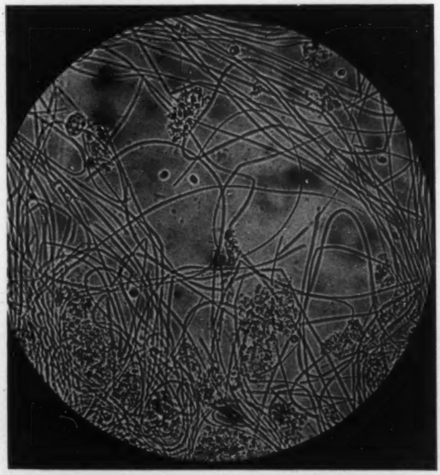

FIG. 9. *Sphaerotilus natans* from river water. Sheath clearly visible. Magn. 300.

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* For this method of cultivation and for a culture of *Sphaerotilus* from river water I am largely indebted to Ir. J. O. Elema in Assen (Holland).

respects the appearance is totally different from the threads present in bulking sludge. Up until now we found it quite impossible to cultivate the sludge organisms on solid media. Material of relatively high purity on agar-plates of different composition has only shown development of many species of ordinary bacteria, but not one colony of thread-like organisms. In considering all observations it seems to be highly improbable that the two mentioned organisms are identical, though there is much to be said in favor of their belonging to the same genus. Before proposing a new name for our organism, I prefer to carry the study of its properties a little further, in order to establish in a still more convincing way its relation to the real cause of the bulking phenomenon. For, evident as this relation may seem to everyone who has had the opportunity of studying the organism both in sludge and in the pure culture, the crucial experiment, viz., causing the sludge disease by adding the organism to healthy sludge, has not yet succeeded, nor has it been possible to indicate the conditions that bring about an abundant development of the threads under apparently quite normal conditions.

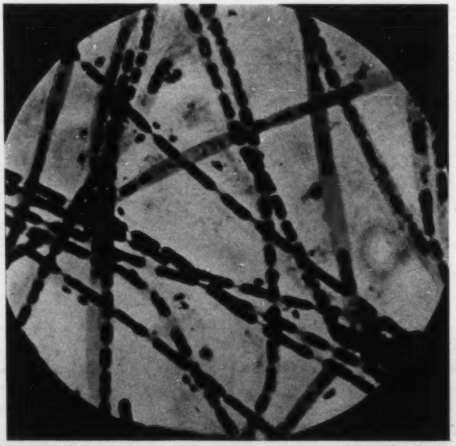

FIG. 10. Stained preparation of Fig. 9. Magn. 1500.

In this respect the following observations may be quoted, made at the sewage works of Amsterdam-West. Before building a large-scale activated sludge plant, a small experimental plant was erected, where

100 cubic meters of settled sewage could be treated per 24 hours. A two-stage treatment was planned and experimented on for many months, using different sludges in both stages, and the most suitable times of aeration have been studied in detail. The interesting observation was made, that in the first stage, where the strong sewage (approximately 800 p.p.m. of permanganate oxygen consumed) was treated, bulking very rarely occurred, while in the second stage, which received the settled effluent of the first (200 p.p.m. of permanganate), the phenomenon was produced within a few weeks' time. The sludge of the first stage was gray in colour and apparently overworked, but continued to do its work successfully; the sludge of the second stage, on the contrary, looked quite normal and healthy, and nevertheless every few weeks turned sick, although purifying relatively unpolluted water!

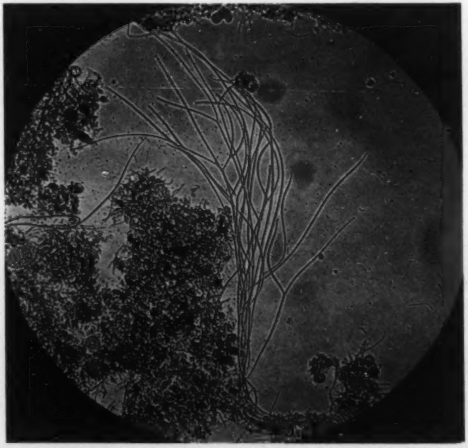

FIG. 11. *Cladothrix dichotoma* in bulking sludge. Magn. 125.

Considering this experience it is difficult to ascribe the phenomenon in the second stage to the presence of sugar, hydrogen sulphide or other substances, already removed in the first stage. Likewise, it seems unlikely that low temperature of the applied air could account for the bulking in the second stage and not in the first. The assumption that bulking did not occur in the first stage because of some toxic substance hampering the development of the threads, could not be maintained when it was proved that the organism grew quite as well in strong as in diluted sewage.

There are still other organisms that have drawn our attention in connection with the phenomenon of bulking. When the sludge treated with Na_2S, as described above, received ordinary sewage to which 0.1 to 0.2 per cent of glucose was added, bulking soon set in, but this time the threads showed a different appearance, and closely resembled the form known as *Cladothrix dichotoma* (Cohn) (Fig. 11). Numerous attempts to grow this organism on solid media of different composition invariably failed. In addition to numerous colonies of bacteria, a few "Sphaerotilus" colonies of the well known type developed, but those of a *Cladothrix*-like organism were not found. At the same time, however, a new type of organism presented itself, being a threadlike organism having a slight resemblance to *Leptomitus*, but of much smaller dimensions (Fig. 12). Pure cultures grew on various kinds of solid media, and it was finally identified as a species belonging to the genus called *Geotrichoides* (Langeron et Talice [10]), of which it forms a species until now unknown.* I propose to give it the name of *Geotrichoides paludosus*. It does not belong to the organisms causing the bulking phenomenon.

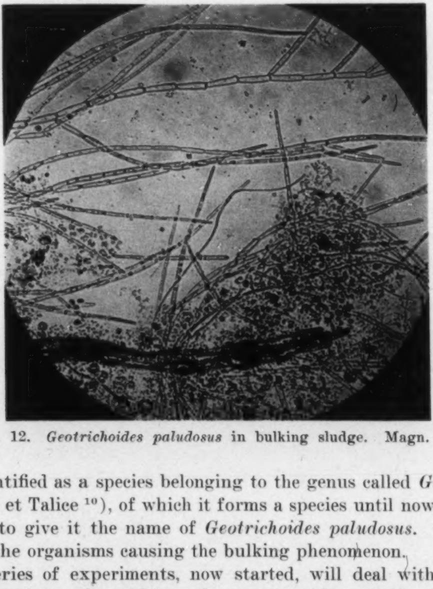

FIG. 12. *Geotrichoides paludosus* in bulking sludge. Magn. 150.

New series of experiments, now started, will deal with the conditions in actual practice which tend to promote the growth of the threadlike organisms, thus inducing the phenomenon of bulking.

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* For this classification my thanks are due to the "Centraal Bureau voor Schimmelcultures" at Baarn (Holland).

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STUDIES ON THE LONGEVITY OF BACILLUS TYPHOSUS (EBERTHELLA TYPHI) IN SEWAGE SLUDGE *

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The use of sewage sludge as fertilizer for truck gardens involves the possibility of infection by pathogenic organisms. Wolman's (1) report in 1924 on this subject indicated that the organisms causing typhoid and paratyphoid fever had a very short life in sewage sludge. Melick (2) in 1917 studied the longevity of these organisms in garden soil and on vegetables. He found that they survived from 29 to 58 days and suggested that it would be very dangerous to fertilize vegetable gardens with material containing these organisms, particularly if the products were to be eaten raw. In view of the widespread interest in the use of sludge for fertilizer and the frequent requests for information concerning the use as fertilizer of sludge from the treatment plants of the Sanitary District of Chicago, it was suggested by Dr. F. W. Mohlman, Director of Laboratories, that a bacteriological study be made of the isolation of *B. typhosus* from various sludges. In the earlier phases of this study such isolation was attempted, and later more extensive studies were made of the viability of various strains of *B. typhosus* inoculated into activated sludge.

Media and Methods

The first problem was to determine the media and methods most applicable for the recovery of these organisms from sludge. This was not a simple problem and six months were spent on it before a satisfactory method was evolved and adopted. In the early work, plain nutrient agar, eosin methylene blue agar, Endo agar, and brilliant green agar (Park and Williams) (3) were used as isolation media. With all of these media a microscopic examination of all colonies on the plate is necessary to find the *B. typhosus*. The microscopic examination is tedious and limits materially the number of samples that can be examined. Of all media studied we preferred the eosin methylene blue medium, but it was not considered satisfactory, since when compared with nutrient agar it was 9.5% productive of total bacteria and 68% of *B. typhosus*. A medium less productive of all bacteria and still more productive of *B. typhosus* is desirable.

Wilson and Blair (4) in 1927 studied the use of a glucose bismuth sulphite agar for the isolation of typhoid organisms from water and sewage. Houston (5) in 1928 reported favorably upon this medium, although he did not think the large amount of brilliant green recommended by Wilson and Blair was necessary. We worked with Wilson and Blair's medium for a month and found it much too inhibitive of *B. typhosus.* We then tried all sorts of modifications of it and ended by changing the concentration of every ingredient in it and adding one more (ferric chloride). This changed it from a 48-hour medium to an 18 to 24-hour medium. The productivity of this new medium with respect to nutrient agar was found to be only 1.8% of all sludge bacteria and 92% for four different strains of *B. typhosus. B. typhosus, paratyphosus A* and some other sulphite reducers give a small colony with a characteristic brown halo on this medium. Microscopic examination of the plates is unnecessary. After counting the typical reacting colonies on these plates they are fished to Russell's double sugar agar, from which they are further confirmed by transfer to mannite broth and to peptone water or lactose broth for an agglutination test with anti-serum. This new medium, followed by confirmation, has proven very satisfactory and has been used on all experiments since June, 1934. Details of the preparation and use of this medium will be published elsewhere.

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* Presented before the Seventh Annual Convention of the Central States Sewage Works Association, Fond du Lac, Wisconsin, Sept. 27, 1934.

Survival of Bacillus typhosus during Aeration in Activated Sludge

An experiment using activated sludge was started June 21, 1934. Twelve liters of raw sewage from the West Side Treatment Works and three liters of settled activated sludge from the Calumet Plant were mixed and aerated in a 20-liter battery jar. The activated sludge used contained 1.2% solids and the aeration mixture contained 3,200 p.p.m. of suspended solids. The aeration mixture was immediately infected, after adding 4 c.c. of dilution water to each of seven 24-hour agar slant cultures of the Rawlins strain of *B. typhosus,* by adding the suspensions of bacteria to the sludge and sewage. This resulted in an initial *B. typhosus* count of 750,000 per c.c. The mixture was aerated by a filtros plate 12 sq. in. in area supplied with air by a Vernon rotary compressor. Samples were taken initially, after mixing and infecting, and after 1, 2, 3, 4 and 5½ hours of aeration. Each sample was planted for bacterial counts immediately after collection. Each sample was then allowed to settle for one hour, after which the supernatant liquor at the top was planted again to determine the numbers of organisms removed by settling.

Table I shows the effect of aeration on the *B. typhosus* content of the mixture. There was apparently no decrease in either the *coli-aerogenes* group or in *B. typhosus* during the first hour of aeration. During the second hour the reduction was about the same for *B. typhosus* as for

Table I.—*Survival of Bacillus typhosus (Eberthella typhi) (Rawlins strain) in Activated Sludge Aeration Mixture at 72° F.*

Sample	With Aeration				
	Nutrient Agar 37° C.—24 Hr. No. per c.c.	*Coli-aerogenes*		*B. typhosus*	
		No. per c.c.	Per Cent Remaining	No. per c.c.	Per Cent Remaining
Initial......	11,000,000	930,000	100	750,000	100
1 hour......	11,100,000	1,500,000	160	870,000	116
2 hours.....	8,750,000	430,000	46	360,000	48
3 hours.....	9,000,000	—		200,000	27
4 hours.....	20,000,000	230,000	25	115,000	15
5½ hours....	24,200,000	—		103,000	14

the *coli-aerogenes* group. After 4 hours reduction of *B. typhosus* was slightly greater than of the *coli-aerogenes* group. The 14 per cent remaining after 5½ hours of aeration indicates that aeration for the periods ordinarily used in practice may not eliminate *B. typhosus* from the sludge.

Removal of Bacillus Typhosus by the Settling Sludge

The removal of *B. typhosus* obtained by settling, following aeration, is shown in Table II. The data show that there was a great difference in the behavior of the *coli-aerogenes* group and *B. typhosus* during the

Table II.—*Survival of Organisms in Activated Sludge Supernatant Liquor After Settling One Hour at 72° F.*

Aeration Time	Remaining in Supernatant Liquor After Settling One Hour					
	Nutrient Agar Count 37° C.—24 Hr.		*Coli-aerogenes*		*B. typhosus*	
	No. per c.c.	Per Cent*	No. per c.c.	Per Cent*	No. per c.c.	Per Cent*
Initial......	2,140,000	19	240,000	26	1,030,000	137
1 hour......	1,550,000	14	110,000	7.3	890,000	102
2 hours.....	1,450,000	17	46,000	10.7	440,000	120
3 hours.....	2,610,000	29	4,300	—	161,000	80
4 hours.....	1,270,000	6.4	15,000	6.5	33,000	29
5½ hours....	1,090,000	4.5	9,300	—	5,800	5.6

*Per cent of numbers present originally in sludge before settling.

first three hours of aeration in this experiment. During this time a high percentage of the *coli-aerogenes* group and of the total bacteria was removed by the settling sludge, while the reduction in the *B. typhosus* count by the settling sludge was small. After 5½ hours aeration, however, all but 5.6% of the *B. typhosus* were removed by the settling sludge. This represents a reduction of *B. typhosus* of from 750,000 per c.c. to 5,800 per c.c. or 99.23%, which is very satisfactory. With pathogens, however, the important thing is not the percentage removal but the number remaining in the effluent. A concentration of 5,800 *B. typhosus* per c.c. is far from innocuous. As this sludge was artificially infected, the numbers of *B. typhosus* were very much higher than would probably ever be found in ordinary sewage. Reports on the removal of *B. typhosus* by the activated sludge process differ considerably. Stewart and Ghosal (6) in 1927 reported a 99% reduction of *B. typhosus* and *paratyphosus* after 6 hours treatment. This checks very well with our results. Bruns and Sierp (7) in 1927 also reported a very high reduction of these organisms. Pesch and Sauerborn (8) in 1929 experimented with *B. paratyphosus B* in activated sludge and reported a 50% reduction after one hour, but no further considerable decrease was noted until the second day. It appears that a high percentage removal of organisms of the typhoid-paratyphoid group is not always obtained.

SURVIVAL OF BACILLUS TYPHOSUS IN STORED OR DIGESTED SLUDGE

Pesch and Sauerborn also found that the pathogens were still numerous in the settled sludge even after prolonged aeration. In this respect our results are similar to theirs. It therefore becomes important to know what the longevity of organisms of the typhoid-paratyphoid group is in stored or digesting activated sludge. A number of experiments on this point have been made in our laboratory. Since Melick (2) (*loc. cit.*) noted considerable difference in viability of different strains of *B. typhosus,* a number of strains were obtained for this work from Dr. F. O. Tonney of the Chicago Board of Health Laboratories. The results of five experiments at 68° to 72° F., using four different strains of *B. typhosus,* are shown in Tables III and IV. In two experiments with Strain I (Rawlins strain) the *B. typhosus* was isolated from the sludge for 13 and 14 days respectively. In one experiment with Strain 2, an initial infection of 8,000 per c.c. was used and we were unable to reisolate any after the infection. This strain was apparently easily affected by unfavorable environment for the organisms died off very rapidly in buffered dilution water. With Strain 3 and an initial infection of 300,000 per c.c. the results indicated 500 per c.c. remained after 8 days, but none were found after 11 days. One experiment with

Strain 4 showed 50 per c.c. on the eighth day but none were found after 13 days. Two experiments were also made with these organisms in Drainage Canal water at 68° and 72° F. In both experiments very high initial infections were used, in one case *B. typhosus* (Rawlins strain) and in the other *B. paratyphosus A* (*Salmonella paratyphi*). The Rawlins strain organisms in canal water died very rapidly until on the tenth day only 3 per c.c. were found and on the thirteenth day none could be found. The *B. paratyphosus A* strain also died very rapidly at first but there were still 4 per c.c. after 13 days at 68° to 72° F.

Table III.—*Survival of Bacillus typhosus (Eberthella typhi) in Stored Activated Sludge at 68 to 72° F. (Strains 1, 2 and 3)*

	Experiment 7—Strain 1 (Rawlins)		Experiment 8—Strain 2		Experiment 12—Strain 3	
Date of Sludge Infection	March 5, 1934		March 20, 1934		March 27, 1934	
Isolation Media	E.M.B. and B.G. agar		E.M.B. and modified W. & B. medium		E.M.B. and modified W. & B. medium	
Age Days	Nutr. Agar Per c.c.	*B. typhosus* Per c.c.	Nutr. Agar Per c.c.	*B. typhosus* Per c.c.	Nutr. Agar Per c.c.	*B. typhosus* Per c.c.
Initial	23,200,000	2,900,000	19,500,000	8,000	10,400,000	300,000
2	11,900,000	550,000	—	—	—	—
3	5,570,000	95,000	13,200,000	None found	—	—
4	6,150,000	70,000			—	—
8	5,570,000	22,000			4,150,000	500
11	14,600,000	13,000			4,040,000	None found
14	6,350,000	1,000			5,900,000	None found
18	—	None found				

Survival of Bacillus Typhosus in Stored Activated Sludge at 50° to 60° F.

It has long been known that intestinal outbreaks have occurred more frequently during the winter months, indicating that *B. typhosus* may survive longer at low temperatures than at high. To determine whether this was also true in stored activated sludge, all samples obtained in the aeration experiment were stored in the ice box and planted from time to time. A maximum and minimum thermometer indicated that the storage temperature varied from 50° to 60° F., which is comparable to

TABLE IV.—*Survival of Bacillus typhosus in Water from Drainage Canal Water and in Stored Activated Sludge, and of Bacillus paratyphosus A in Canal Water, at 68 to 72° F.*

(Bacteria per c.c.)

Infected With	Stored Activated Sludge						Drainage Canal Water					
	B. typhosus Strain 4			*B. typhosus* Strain 1			*B. typhosus* Strain 1			*B. paratyphosus A* (*Salmonella paratyphi*)		
Age Days	Nutr. Agar 37° C. 24 hr.	*Coli-aero.*	*B. typhosus*	Nutr. Agar 37° C. 24 hr.	*Coli-aero.*	*B. typhosus*	Nutr. Agar 37° C. 24 hr.	*Coli-aero.*	*B. typhosus*	Nutr. Agar 37° C. 24 hr.	*Coli-aero.*	*B. paratyphosus A*
Initial	10,700,000	700,000	835,000	21,600,000	230,000	5,800,000	10,300,000	43,000	6,300,000	—	43,000	18,900,000
2	—	—	8,180	18,200,000	750,000	530,000	5,500,000	23,000	495,000	650,000	23,000	5,600
5	8,100,000	—	3,200	—	—	—	—	—	—	—	—	—
6	6,800,000	—	2,700	9,050,000	150,000	5,000	300,000	1,500	185	160,000	1,500	220
8	2,100,000	—	50	2,350,000	43,000	34	117,000	300	24	54,000	—	7
10	—	—	—	9,200,000	9,100	—	85,000	750	3	62,500	1,500	22
13	—	43,000	None found	—	9,100	12	42,500	—	None found	42,500	2,400	4
15	2,500,000	43,000	"	—	—	—	—	—	—	—	—	—
20	3,400,000	2,300	"	—	—	—	—	—	—	—	—	—

TABLE V.—*Survival of Bacillus typhosus (Eberthella typhi) in Stored Activated Sludge at 50° to 60° F. (Rawlins Strain)*

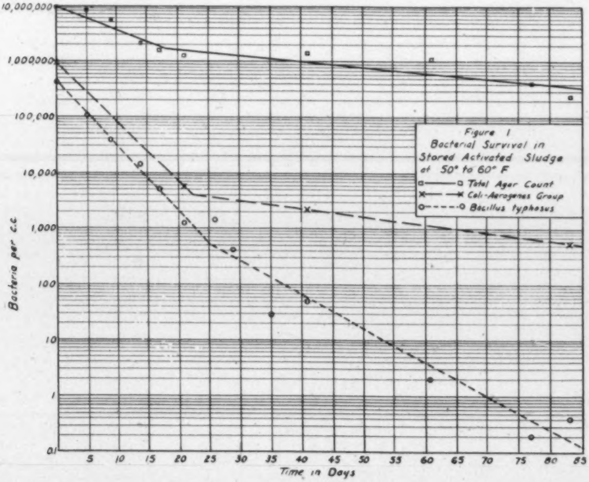
	Aeration Mixture		Stored Activated Sludge									
Aeration Time	0		1 hour		2 hours		3 hours		4 hours		5½ hours	
Digestion Time Days	Total Bact. 1,000 per c.c.	*B. typhosus* per c.c.	Total Bact. 1,000 per c.c.	*B. typhosus* per c.c.	Total Bact. 1,000 per c.c.	*B. typhosus* per c.c.	Total Bact. 1,000 per c.c.	*B. typhosus* per c.c.	Total Bact. 1,000 per c.c.	*B. typhosus* per c.c.	Total Bact. 1,000 per c.c.	*B. typhosus* per c.c.
0	11,000	750,000	11,100	870,000	8,750	360,000	9,000	200,000	20,100	115,000	24,200	103,000
5	7,500	170,000	7,950	196,000	9,100	124,000	7,300	67,500	7,950	20,000	6,600	17,500
9	6,900	72,000	5,550	78,500	5,600	55,500	5,350	42,900	6,850	7,150	6,300	8,780
14	1,950	12,800	1,950	15,700	1,950	13,500	2,200	13,100	2,600	4,300	1,650	410
17	—	4,400	—	—	—	8,950	—	1,750	—	2,400	—	1,300
21	760	750	1,710	2,140	1,330	820	2,490	575	1,770	300	2,360	3,800
26	—	—	—	2,100	—	2,500	—	104	—	100	—	100
29	1,340	150	1,430	365	1,150	755	1,400	125	1,610	22	1,580	N.F.
35	—	15	—	50	—	29	—	5	—	12	—	"
41	890	N.F.	1,140	39	940	100	2,450	14	1,750	6	1,940	"
61	—	—	930	3	1,250	2	1,100	1	1,130	N.F.	—	—
77	—	—	310	0.4	540	0.2	350	N.F.	410	—	—	—
83	—	—	164	0.8	374	N.F.	202	0.4	—	—	—	—

TABLE VI.—*Percentage of Bacteria Remaining in Stored Activated Sludge at 50° to 60° F.*

Sludge Digestion Time Days	Total Bacteria Nutr. Agar, 37° C.—24 hr.				*Coli-aerogenes* Group				*Bacillus typhosus* (Rawlins)			
	No Aeration	Mean 2 hr. Aeration	Mean 4¾ hr. Aeration	Mean All Sludge	No Aeration	Mean 2 hr. Aeration	Mean 4¾ hr. Aeration	Mean All Sludge	No Aeration	Mean 2 hr. Aeration	Mean 4¾ hr. Aeration	Mean All Sludge
0	100	100	100	100	100	100	100	100	100	100	100	100
5	68	84	32	61	—	—	—	—	23	29	17	23
9	63	57	30	50	—	—	—	—	9.6	13	7.3	9.9
14	18	21	10	16	—	—	—	—	1.7	3.2	2.2	2.4
17	—	—	—	—	—	—	—	—	.60	1.2	1.7	1.17
21	6.9	19	9.3	11.7	.47	.59	3.0	1.35	.10	.26	1.9	.75
26	—	—	—	—	—	—	—	—	—	.35	.09	.22
29	12.0	14	7.2	11.0	—	—	—	—	.02	.094	.01	.041
35	—	—	—	—	—	—	—	—	.002	.006	.005	.0043
41	9.0	16	8.3	11.1	.26	.22	1.5	.66	—	.011	.003	.007
61	—	11	5.1	8.0	—	—	—	—	—	.0004	—	.0004
77	—	4.2	1.9	3.0	—	—	—	—	—	.00004	—	.00004
83	—	2.6	—	2.6	—	.056	—	.056	—	.00009	—	.00009

the winter temperatures of unheated digestion tanks in the northern cities of the United States. The Rawlins strain was used in these tests because the experiments at 68° to 72° F. indicated that this strain outlived all the others tested. The data obtained with the six sludges that had had various periods of aeration from 0 to 5½ hours are shown in Table V. The *B. typhosus* disappeared first in the sludge that had been aerated longest. This was to be expected because this sample also had the lowest initial number. *B. typhosus* was not isolated from this sample after the 26th day, at which time the results indicated that there were still 100 per c.c. remaining. Based on later experience, it is believed that *typhosus* might have been recovered after the 26th day if it had been possible to pour a large number of plates.

The next sludge from which the typhoid bacillus disappeared was the initial mixture which had not been aerated. In this sample *B. typhosus* was not isolated after the 35th day. In the sample that was aerated 4 hours and then stored, *B. typhosus* persisted and was re-isolated until the 41st day. In the three samples with the intermediate aeration and having higher initial *B. typhosus* counts the results indicated that *typhosus* persisted in small numbers even after 83 days. Mean results for the three sludges having the intermediate aeration and for the two having the longer aeration periods were calculated. From



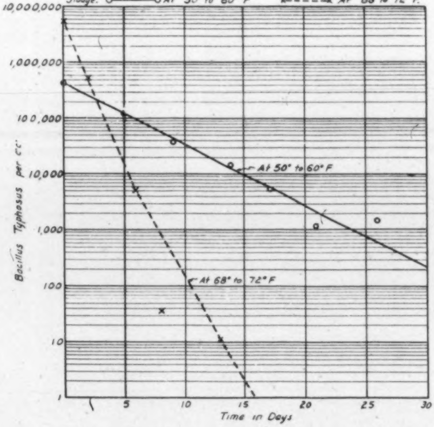
these results the percentage of bacteria remaining after various periods for the total counts, the *coli-aerogenes* group and *B. typhosus* were calculated. These results are given in Table VI, and indicate that the death rate of these groups in the stored sludge are not influenced by the aeration period. Consequently, the mean percentage of bacteria remaining at 50° to 60° F. in all sludges have been calculated for all groups.

The average counts for the intermediate aeration sludges have been plotted and are shown in Figure 1. These curves show that the *B. typhosus* death rate is considerably greater than the *coli-aerogenes* group death rate. However, there seems to have been a reduction in the *B. typhosus* death rate after about the 25th day and the surprising fact is that viable organisms were isolated after 83 days.

A comparison of the death rate curves of the same strain of *B. typhosus* at 50° to 60° F. and 68° to 72° F. is shown in Figure 2. A remarkable increase in the death rate with the temperature increase is shown. This strikingly emphasizes the importance of the temperature factor on the death rate of these organisms.

Figure 2

Survival of Bacillus Typhosus (Rawlins Strain) in Stored Activated Sludge. o——o At 50° to 60° F x- - - - -x At 68° to 72° F.



Two other factors which have an important bearing on the *B. typhosus* death rate, but have not been studied directly in this paper, are organic nitrogenous matter and plankton. Vacek (9) in 1932 found that less than 0.3% urine in water served as a nutrient material and favored the multiplication of *B. typhosus.* His experiments with *Euglena* and *Polytoma* showed the detrimental effect of plankton on *B. typhosus.* Vacek points out that these two factors are connected with the old bacteriological experience that a good potable water if polluted by effluents can become a more dangerous source of typhoid infection than a frequently polluted water which often contains a sufficient microflora and microfauna to prevent the growth of *B. typhosus.*

Search for Bacillus Typhosus in Sewage and Sludge

Houston (5) in 1928 and 1929, using Wilson and Blair's medium, succeeded in isolating *B. typhosus* from raw Thames River water on four occasions. To do this, 68 samples of water were examined and 3,853 colonies were studied. The successful isolation of *B. typhosus* was therefore accomplished only after an enormous amount of work. In 1930 Houston was again the first to report the successful isolation of *B. typhosus* from raw sewage. In this investigation 34 samples were examined. Each sample was streaked on 20 Wilson and Blair medium plates and a total of 5,624 colonies were studied. This resulted in four successful isolations. Gray (10) in 1929 reported seven isolations of *B. paratyphosus* out of 20 samples of Edinburgh sewage. The seven isolations were all from one district and that district had suffered from paratyphoid in 1927. Begbie and Gibson (11) in 1930 examined samples from 58 main sewers of the Edinburgh system and obtained seven isolations of organisms identified as *B. paratyphosus B* (Schottmüller). These organisms were also isolated by Wilson and Blair's medium and by the brilliant green enrichment method. Fleming (12) in 1933, using a Wilson and Blair liquid enrichment medium, successfully isolated both *B. typhosus* and *B. paratyphosus B* from the sewage of a mental hospital. Houston (5) in 1931 and 1932 reported the isolation of numbers of *B. paratyphosus B* in Epping sewage following a paratyphoid epidemic. As many as 3,400 organisms per c.c. were found in the raw sewage and up to 355 per c.c. in the effluent. Continuous bacteriological examination of the sewage and effluent of this district was carried on and it was found that *B. paratyphosus B* were still present in the sewage a year after the disappearance of all diagnosable paratyphoid.

All of these studies show that the typhoid-paratyphoid group of organisms may be present in considerable numbers following epidemics, but at other times they are very difficult to isolate. Houston believes that *B. paratyphosus B* are usually absent in 0.1 c.c. of sewage and in 1 to 2.5 c.c. of sewage effluents. In his 1930 investigations of raw London sewage (*loc. cit.*), four isolations of *B. typhosus* were made from 27 samples of 0.1 c.c. each.

E. W. Coulter and R. M. Brown made the first systematic search for *B. typhosus* in sewage sludge in our laboratory late in 1933. They streaked the sludge on plates of the isolation media and after microscopic examination of the colonies fished suspected ones for confirmation. Brilliant green agar, eosin, methylene blue agar, and Wilson and Blair's medium were used. From December 18, 1933, to February 1, 1934, they examined three samples of the activated-sludge mixed liquor from the North Side Sewage Treatment Works, and six samples of Imhoff sludge from the West Side Treatment Works. A total of 483 colonies were studied by them but no *B. typhosus* were found.

Following this it was decided to use a pour-plate method in order that an approximate estimation of the numbers of *B. typhosus* could be made if they were found. In this work a modified Wilson and Blair medium was used and this medium was changed from time to time, as the experiments that were being carried on simultaneously indicated the advisability of the changes. From March 6, 1934, to June 5, 1934, thirteen samples of activated sludge were examined. Three of these were directly from the North Side plant while the rest were obtained from the North Side plant sludge as discharged at the West Side Plant. A total of 531 colonies were studied from these samples and two positive isolations of *B. typhosus* were obtained. Both isolations were obtained from .01 c.c. portions of North Side activated sludge collected at the West Side plant. One occurred March 27 and the other May 16, 1934. The mean *coli-aerogenes* index in these sludges is about 770,000 per c.c., so the indications are that in the samples in which *B. typhosus* were isolated the typhoid-coli ratio was about 1 to 7,700.

It is realized that sludge for fertilizer is usually obtained after filtering and drying activated sludge and after drying Imhoff sludge on sand beds. Limitations of time prevented study of dried sludges in this investigation. It is well known, however, that drying alone immediately reduces the number of viable *B. typhosus* by a large percentage.

Summary and Conclusions

1. Samples of activated sludge from the North Side Treatment Works were carefully examined for the presence of *B. typhosus*. Isolations of *B. typhosus* were obtained in two cases. In these samples the ratio of *B. typhosus* to the *coli-aerogenes* group was about 1 to 7,700.

2. The survival of *B. typhosus* in artifically infected aeration mixture was studied. It was found that the percentage of *B. typhosus* remaining in the sludge for various periods of aeration was slightly less than for the *coli-aerogenes* group. The initial number of *B. typhosus*

in the aeration mixture was 750,000 per c.c. After 5½ hours of aeration 103,000 per c.c. or 14 per cent remained.

3. The removal of *B. typhosus* by the settling sludge after various periods of aeration was studied. Following the first three hours of aeration practically no removal was obtained by allowing the sludge to settle. A large percentage of the *coli-aerogenes* group, however, was removed by the settling sludge after three hours of aeration. After 5½ hours of aeration all but 5.8% of the *B. typhosus* were removed by the settling sludge. This amounts to a total removal of 99.2% of the *B. typhosus* by settlement of the activated sludge.

4. The survival of *B. typhosus* in stored activated sludge at 50° to 60° F. and 68° to 72° F. was investigated. Four strains of *B. typhosus* were used, including the Rawlins strain and three others freshly isolated from patients or carriers by the Chicago Health Department laboratory. The results at 68° to 72° F. indicated that one of these strains died off very rapidly, two others survived from 8 to 10 days, while the Rawlins strain was re-isolated after 13 and 14 days. The Rawlins strain survived in Drainage Canal water for 10 days and a strain of *B. paratyphosus A* survived for 13 days.

At 50° to 60° F. the Rawlins strain survived for a much longer period, thus indicating the great influence of temperature upon survival. At this temperature viable *B. typhosus* were re-isolated from the sludge after 83 days. Experiments with six sludges indicated that the time of aeration did not influence the percentage survival in the stored sludge.

From this study it is concluded that wet activated sludge can not be considered innocuous. At times it may be quite infectious. Caution should be observed when it is used as a fertilizer for truck gardens.

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OPERATION EXPERIMENTS AT THE INDIANAPOLIS ACTIVATED SLUDGE PLANT*

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The Indianapolis activated-sludge plant is of insufficient size to treat all of the sewage. Because of this limitation, operation has been varied for the purpose of removing as much of the B.O.D. and suspended solids as possible. In 1931, the junior author, in charge of activated-sludge plant operation, increased the rate of treatment and reduced the returned sludge to such an extent that mixed liquor solids seldom exceeded 0.15 per cent, with a creditable, though unsatisfactory, purification. This experience suggested the experiment of operating with no returned sludge. For this purpose, one unit, with a million gallon holding capacity, was operated without sludge return for a considerable period in 1932. The results were so encouraging that no sludge was returned to the entire plant after October, 1932, except for about two months in the summer of 1933. For the year 1933, operating and analytical data are available for comparison with the operation of the same plant in earlier years, with the return of sludge in the usual way. The year 1931 is chosen for comparison since it is the last full year during which the plant was operated on the activated-sludge principle and is the year in which the greatest removals of solids and B.O.D. were effected.

It is impossible to separate the data for the two months in 1933 when activated sludge was used. The results obtained during this period were not as good as in the same period in 1931 so that the additional removals obtained in 1933 cannot be attributed to the period in which activated sludge was used.

Table I

	Thousand Lb. Solids	Removed B.O.D.	Lb. Removed per Million Cu. Ft. of Air		Dollars per 1000 Lb. B.O.D. Removed
			Solids	B.O.D.	
1931	12,728	12,168	1,508	1,442	5.33
1933	20,912	17,449	2,226	1,857	3.46

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* Presented before the Seventh Annual Convention of the Central States Sewage Works Association, Fond du Lac, Wisconsin, September 28, 1934.

The first two columns are included to indicate the size of the experiment. As a matter of economy the maximum rate of pumpage of clarified sewage to the activated-sludge plant was limited to 43 m.g.d. for the first six months of 1933. If all of the sewage had been treated, the removals would have been greater and the unit cost lower. Table I shows that the solids removed amounted to 64 per cent more in 1933 than in 1931 and the B.O.D. 43 per cent more, at a unit cost 35 per cent less.

Under the plain aeration plan, the space usually occupied in the aerator by the returned sludge is available for sewage, so that the rather long average aeration period of 7.5 hours is realized. The sludge produced in plain aeration is very different from activated sludge, as is shown in Table II.

TABLE II

	Activated Sludge 1931	Plain Aeration Sludge 1933
% Dry Solids as Wasted	1.31	4.26
Lb. Dry Solids per M.G.	1,828	1,308
% Nitrogen	5.04	3.93
% Ash	34.68	32.01
% Ether Soluble	8.46	24.21

Plain aeration sludge is removed only once in 8 hours and in this time, and on account of its specific gravity, greater concentration of solids is obtained. The data indicate that plain aeration produces 72 per cent of the sludge produced by activated-sludge operation, but when sludge productions are calculated to grease-free weights, sludge production per million gallons by plain aeration is about 59 per cent as much as by activated sludge operation. The nitrogen is reduced 22 per cent but the ash is reduced only 8 per cent. The large ether-soluble content is surprising and indicates that biologic action in plain aeration is, in some respects, different than in the presence of activated sludge. The digestion of plain aeration sludge with primary settled sludge in deep earthen digestion pits has caused no odor and tests indicate that the grease content disappears at a fairly rapid rate.

The effluent from the plant during plain aeration is not attractive, being quite turbid except on Sundays and holidays, when it clears up remarkably. At such times the plant has the odor of an activated-sludge plant. The most surprising characteristic of plain aeration is found in the bacteriological examinations, in which the final effluent shows an increase over clarified sewage of 4 per cent lactose fermenters, 13 per cent bacteria at 37° and 36 per cent at 20°, while the normal reductions, using activated sludge, range from 97 to 99 per cent. The increase is not due to the agitation and dispersion of suspended solids during aeration.

Rate of Oxidation.—Plain aeration of sewage throughout the year under Indianapolis conditions, although showing markedly decreased percentage removal, results in the removal of a considerably larger weight of B.O.D. than can be obtained by activated-sludge treatment of only a part of the sewage flow. It was thought probable that plain aeration would remove the most easily oxidizable material, the remainder going to the stream in a condition which would (1) require oxygen at a slower rate, (2) reduce the peak load in the river immediately below the plant outfall, (3) push the zone of greatest concentration downstream and reduce its intensity. In order to study these assumptions, twelve samples of influent and effluent were collected. The influent samples were allowed to stand for thirty minutes before dilutions were made, in order to compensate for the sedimentation taking place in the effluent samples in the activated-sludge plant settlers. Five portions of each dilution were incubated, one of each being examined at the end of each day for five days. Later, eight similar sets of samples were collected and incubated, one each of influent and effluent being examined at the end of each six-hour period for the first day and finally at the end of five days. The average results in Figure 1 show that the influent and effluent require oxygen at a very similar rate.

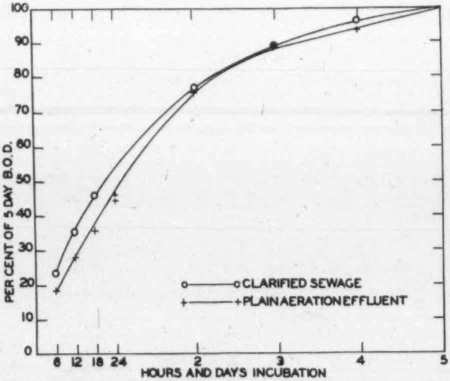

FIG. 1.—Rate of satisfaction of 5-day B.O.D. by clarified sewage and final effluent, during plain aeration.

Increased Submerged Surface Area.—The purification observed in plain aeration, and reported with aerated filters and brush aerators, suggested that biologic growth on the walls of the aerators might assist purification. To throw some light on this question, two 5-gallon bottles were cleaned, filled with sewage and aerated for eight hours. Both were then emptied, one was cleaned well and both were refilled with fresh sewage. This cycle was repeated for a number of days, always cleaning only one and the same bottle between aeration periods. In a few days the sewage in the uncleaned bottle showed coagulation and clarification while no visible change took place in the sewage in the cleaned bottle.

This indicated that an increase in the submerged surface area of an aerator should improve the extent, or rate, of purification. Consideration was given to a number of means to obtain greater contact surfaces. Eventually a number of glazed hollow building tile were dipped in cement mortar, to roughen the surface, and stacked chimney fashion on railroad rails supported 24 inches from the floor and directly over the air diffusers. The submerged area of the walls and bottom of the aeration tank was 26,500 sq. ft. and this was increased by 60,000 sq. ft. of tile surface.

This aerator, with submerged surfaces, and another, duplicating it in other respects, were operated without returned sludge for more than three months. The average results are shown in Table III.

Table III

	Analysis of Effluents	
	With Submerged Surface Added	Without Additional Submerged Surfaces
Sewage Flow, M.G.D.	3.30	3.18
Air, M.C.F. Day	1.52	1.66
Cu. Ft. Air per Gal.	.46	.52
Air Period, Hr.	7.73	8.01
D.O., P.P.M.	2.8	2.1
Susp. Solids, P.P.M.	39.6	40.8
B.O.D., 4 P.M.	95.2	97.8
Oxygen Consumed, P.P.M., 4 P.M.	29.2	29.1
Total Organic Nitrogen, P.P.M.	16.5	16.8
Lactose Ferm. 1000 per Ml.	270	290
Thousand Bacteria per Ml. 37° C.	4200	5400
20° C.	7700	8800

Despite careful manual control the aerator with additional submerged surface area received slightly more sewage and less air. The effluent was nevertheless slightly better than the effluent from the other tank, but the advantage was obviously insufficient to warrant the installation of additional submerged surface area, although observation of the two effluents indicated a much greater difference than the figures show.

Aeration of Sewage Before Activated Sludge Treatment.—Studies of the process during plain aeration demonstrated that a great deal of purification took place in a comparatively short aeration period and encouraged the experiment of using plain aeration prior to activated-sludge treatment. The arrangement of the plant prevented intermediate settling between plain aeration and activated-sludge treatment, although such settling was shown to be desirable by laboratory tests. Without removing the tiles used in the submerged-contact experiment, provision was made to add returned sludge at any one of a number of points throughout the aerator. When it was added at the half-way point, 238 ft. from the influent end, it soon worked back in reducing concentration nearly to the influent end. This seems to be caused by the mixing and dividing action of the rising column of air from the diffusers, which are set checker-board fashion, and which action accounts for the smoothing out effect reported previously by one of us (C. K. Calvert, "The Hourly Variation of Indianapolis Sewage," THIS JOURNAL, **4**, 815 (1932)).

It was thought that the aeration of sewage before the addition of activated sludge might (1) remove volatile material, (2) mix the incoming sewage, and (3) result in better operation. In order to try the experiment, most of the building tile were piled in the first fourth of the aerator and a wall was built across the tank at the quarter point. Activated sludge was added immediately beyond the wall. The results of analyses of samples of the effluent from this tank show that some improvement has taken place, but it is doubtful if the expense of such construction is justifiable.

Conclusions.—1. The plain aeration of sewage in the present plant removes a greater weight of solids and B.O.D. than can be removed by the same plant using the activated-sludge process.

2. With the present plant, the unit cost of removal of solids and B.O.D. is lower using plain aeration.

3. The digestion of sludge from the plain aeration of sewage offers no difficulties, and the greater concentration of the sludge wasted has resulted in economy of digestion pit capacity.

4. It appears that no reasonable increase in the amount of submerged contact surface will produce increased purification of the Indianapolis sewage commensurate with the cost of installation.

5. The observed results of pre-aeration, as practiced in this experiment, do not warrant its use.

RELATION BETWEEN DRAINABILITY OF SLUDGE AND DEGREE OF DIGESTION *

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Based upon common experience it would be expected that the rate and possibly the degree of drainability of digested sludge depend upon the progress and degree of decomposition of the material. It has been assumed that poorly digested sludge drains with greater difficulty than well digested sludge. However, Pearson and Buswell,[1] using sludges from an experimental plant and from several different treatment plants in Illinois, concluded that "the draining quality of a digested sludge is roughly inversely related to its ripeness and to the ease with which the non-draining moisture is removed." In other words, the more thoroughly ripened the sludge, the poorer its draining qualities.

Practice has shown that a well digested sludge, or a sludge which has recently undergone active decomposition, drains and filters more rapidly than partly decomposed material, but it has also been reported that sludge stored for a considerable time after active decomposition has ceased filters poorly because it is "dead." It is commonly believed that the gas bubbles present in the sludge buoy the sludge particles, allowing more rapid separation of the water, and that the bubbles make the drained sludge more porous so that evaporation (drying) is enhanced. The practice to add alum to poorly digested sludge or to slimy scum developed years ago was based upon the observation that either the alum reacts with the acid carbonates present and releases carbon dioxide, or that the alum, while coagulating the smaller particles, causes the release of a film of gas around the flocs, finally forming by coalescing larger bubbles which make the material more porous and drainable. The mechanism would therefore be essentially a flotation process. Similar results can be obtained with other chemicals and gases. Copper sulphate, for instance, produces similar results and in addition retards odors, the production of which is often associated with poorly digested sludge or stale settled solids. Since the gas distributed through the sludge is such an important aid in dewatering or drying, it would be logical to assume that with the increase in gas production in a digesting mixture the drainability of the material would increase.

The practical importance of this problem led us to determine ex-

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* Journal Series Paper, N. J. Agr. Exp. Sta., New Brunswick, N. J., Dept. Water and Sewage Res.

[1] Pearson and Buswell, *Ind. Eng. Chem. Anal.*, Ed. 3, 359, 1931.

perimentally whether or not a definite relation existed between gas production and the rate and degree of dewatering of sludge.

METHOD

A large quantity of a 1 to 1 mixture of fresh solids and ripe sludge was made on the basis of volume and 300 c.c. portions were distributed into a series of bottles. One bottle was connected to a gas measuring device and all were incubated at 20–22° C. At intervals the bottles were taken out and the sludge was filtered through a sand filter. The filter was made out of 30-mesh screen, 5 inches in diameter, onto which was poured 30 grams of filter sand, making a layer ¾-inch thick. A piece of cheesecloth was laid on the sand and the filter was supported over a ringstand and funnel. The sand was wetted with water and the sludge poured carefully on the surface. The filtrate was measured in a graduated cylinder at uniform intervals. All determinations were run in duplicate. After each test the sludge was removed by means of the cheesecloth and the sand dried and ignited. The same lot of sand was used throughout the experiment.

RESULTS

The average results of several trials obtained at weekly intervals during digestion are shown in Table I. Filtration was continued for 24 hours, but the quantity of liquid drained off after 24 hours was not

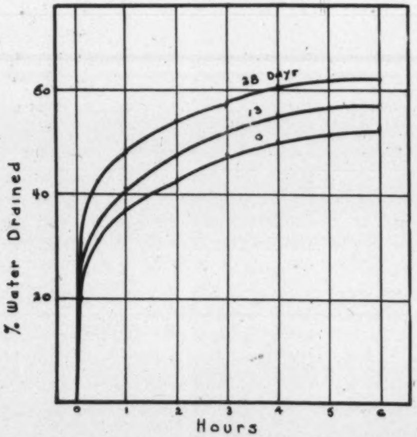

FIG. 1.—Percentage of original volume of water drained.

materially greater than after 6, therefore all comparisons are made for the first period. The amounts of filtrate given were secured from an initial sludge mixture volume of 300 c.c. With the increase in digestion time the volume of filtrate increased. A difference in the amount of filtrate obtained after 5 minutes of draining was still noticeable after 6 hours. The percentage differences, based upon the initial volume of sludge mixture, for the 0, 13 and 28-day digestion periods are shown in Figure 1. The curves for the other two mixtures fall in between those illustrated. It can be observed that the rate of filtration during the first hour of filtering increased progressively with the increase in time of digestion. The differences throughout the filtration period are perhaps shown more clearly by plotting the percentage increase in filtrate from the different mixtures, using 0 days digestion time as basis for comparison. These percentage differences are shown in Figure 2, indi-

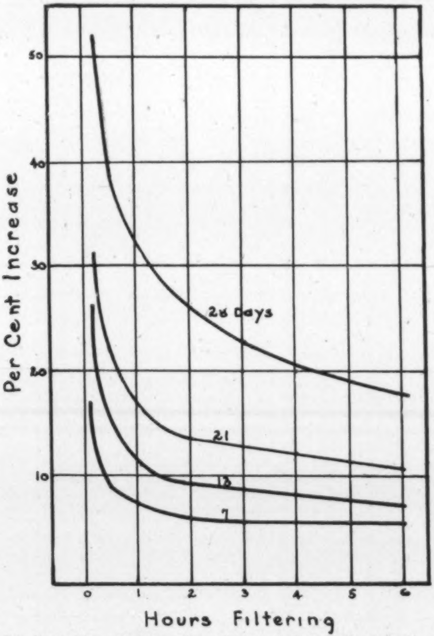

FIG. 2.—Percentage increase in volume of filtrate during digestion.

cating that filtrability increased more rapidly between the 21 and 28-day digestion period than during any other similar period. The differences in filtrability are most marked during the first hour, but if the 6-hour results are compared on a time basis, namely the time required to obtain equal quantities of filtrate, the differences are even more striking (Fig. 3). The time required at the beginning of digestion to obtain 157 c.c. of filtrate from 300 c.c. sludge mixture was 6 hours. This was reduced to about 3 hours at the peak of gas production and to less than 2 hours when digestion was completed.

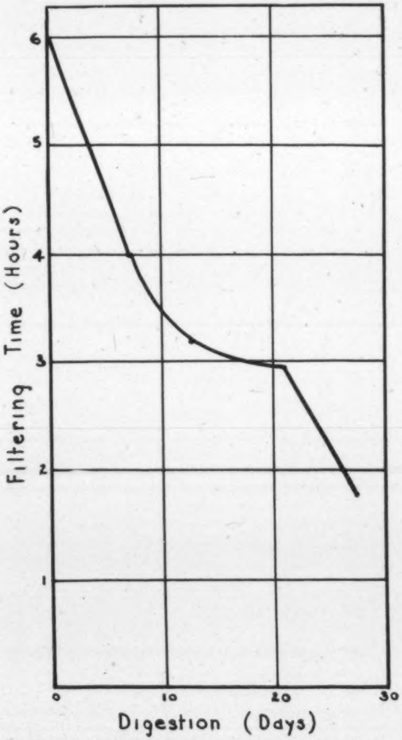

FIG. 3.—Filtering time required to obtain equal quantities of filtrate during digestion.

The relation between the progress of digestion, as indicated by daily and accumulative gas production, and the percentage increase in filtrate is shown in Figure 4. The increase of filtrate in percentages over 0 hours after a draining time of 5 min. and 6 hours are given, rather than the total quantities of filtrate, because it indicates more clearly the changes in filtration rates in the course of digestion. It will be seen that the drainability of the sludge increased rapidly with the increase in daily gas production until the peak of gasification was nearly reached. When the gas production fell sharply the drainability did not increase, but as soon as as production dropped to a low rate the drainability again increased. If the gas present in the sludge was primarily responsible for the increase in filtrability, it might be assumed that the drainability of the sludge between the 7th and 21st day of digestion should be

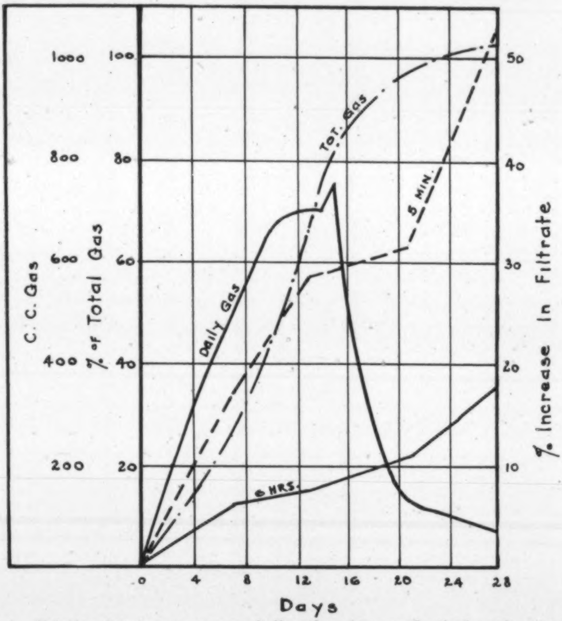

FIG. 4.—Relation between progress of digestion (gas production) and percentage increase in volume of filtrate.

constant, because during that time the sludge held all the gas possible. Instead, the drainability increased constantly. It appears, therefore, that the nature of the solids and the stage of decomposition of the material holding the water is an important factor in drainability of digesting sludge. The failure of filtrability to increase during the later period of rapid gasification was probably due to the increase in finely divided and colloidal material in the liquid, which clogged the pores of the filter. After the peak of gasification was over, part of this finely divided material was destroyed and another portion might adhere to the larger particles.

How much the "sliminess" of the material affects the drainability, and what the effect is with progressive destruction of this viscous material during digestion, may perhaps be shown by calculating the increase in the rate of drainability during the first 5 minutes as compared with the drainability after 6 hours. If the water is primarily held or is caused to be held by the material responsible for producing most of the gas (easily decomposable material), the water drained off in the first few minutes should materially increase. The percentages drawn off after 5 minutes were as follows:

Days Digestion	% Water	% Gas Produced
0	38	0
7	42	26
13	45	60
21	45	93
28	49	100

It appears that in 5 minutes 11 per cent (31 c.c. from 300 c.c. sample) of the total water drained off more rapidly after digestion, as compared with the undigested mixture. This corresponds to an increase of 9.4 per cent (28 c.c.) after draining 6 hours, for the digested mixture over the undigested material. In other words, the whole increase in drainability was apparent during the first 5 minutes filtering. (For further details see Table I.)

Although, after the peak of gasification has been reached, filtrability increases for some time, the ease of filtering decreases upon prolonged storage. From the results reported and others available, it does not appear, however, that the filtrability ever reaches the low value of the original mixture. Nevertheless, the longer the storage of digested sludge, the more "dead" the sludge becomes, the more difficult filtering becomes. The apparent reason is that the longer the sludge is stored, the finer the particles become and the less gas is entrained. This fine material settles quickly and compacts and fills the pores near the surface of the sand. Whereas the undigested material forms a slimy film which prevents drainage, the digested is so finely divided that clogging results.

TABLE I.—*Amounts of Liquid Filtered Through Sand After Different Periods of Digestion (Volume of Sludge 300 c.c.)*

Time	Digestion Time in Days				
	0	7	13	21	28
5 min.	60	70	76	79	91
10 "	71	79	85	89	103
20 "	84	92	97	103	117
30 "	92	100	105	110	128
45 "	102	110	116	119	136
60 "	110	118	122	127	144
2 hrs.	128	137	140	146	162
3 "	142	150	155	158	174
4 "	155	163	168	172	185
6 "	157	166	169	175	185

We have found that well digested or partly digested sludges obtained from different plants behave differently during and after digestion. When trade wastes containing quantities of finely divided material, or substances which disintegrate rapidly, are present in the sewage the effect on the degree of filtrability of the sludge may be appreciable. In addition, the time of storage required for sludges (containing trade wastes) to improve filtrability may be much less than that required for domestic sludges.

As an example of lower drainability during digestion, and after digestion is completed (time of storage), the results from a mixture of fresh solids and ripe sludge obtained from the Freehold, N. J., plant are graphically shown in Figure 5. The Freehold sewage contains considerable quantities of dye wastes. The results show again that the drainability of the sludge increased with the rate of gas production, but a few days after the peak of gasification was reached drainability decreased sharply.

The results obtained by Pearson and Buswell were from sludges secured at the experimental plant and three other plants. The erratic results obtained may be due to the fact that sludges from different plants behave differently. Even sludges from the same plant exhibit differences in drainability. Our experiments also have shown that the drainability of partly digested sludge is usually better than of undigested material. It should be understood, however, that this holds for sludges draining on sand beds and not for the filtrability of sludge treated chemically for dewatering on vacuum filters, etc. The iron salts commonly used as an aid in dewatering cause pronounced chemical and physical changes. The effect of chemicals, such as alum, appears to be principally in stimulation of and release of gas. It follows that the addition of alum will help most when either the sludge is poorly digested or has been stored too long.

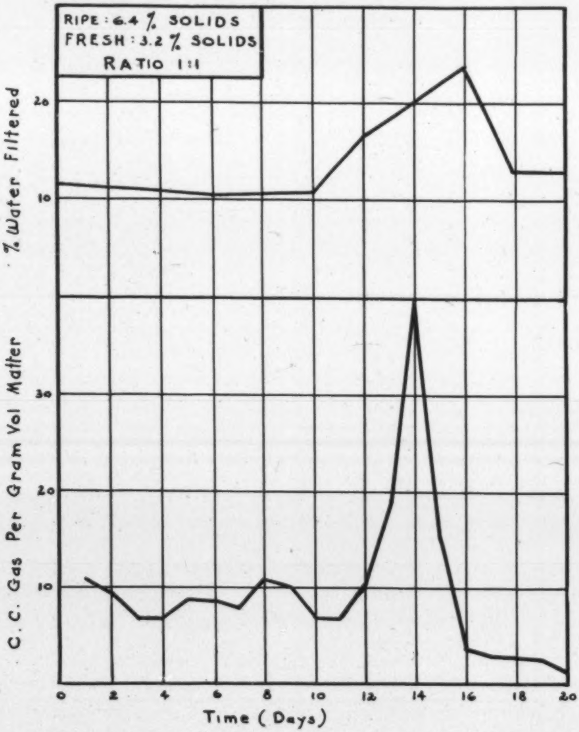

FIG. 5.—Relation between filtrability and gas production of sludge containing trade waste.

Additions of alum to well digested sludge containing quantities of gas will be ineffective. Laboratory experiments indicate that the addition of gases or air may be effective under certain conditions.

The drainability of digesting mixtures appears to be affected by (*a*) the type and quantity of material in suspension and solution (quantity and degree of destruction of gelatinous material, quantity and type of substances in solution, degree of fineness, etc.), (*b*) gas present. The practice of drawing sludge when it is freely gasifying would therefore produce best conditions for rapid draining on sand beds.

The ease with which the non-draining moisture is removed is not necessarily affected by the same factors, or to the same degree by all factors, that affect the release of easily drainable water. It is well known that undigested sludge (fresh solids) dewater more rapidly when treated with certain chemicals than digested sludge, but a discussion would lead us too far afield at present. Papers dealing with artificial dewatering of different types of sludges are in process of preparation.

SUMMARY.

Laboratory experiments made on the drainability of digesting sludges showed that:

1. Drainability increased with increase in gas production until and shortly after the peak of gas formation had been reached.
2. Storage of digested sludge decreased the drainability.
3. The original nature of the sludge affected drainability. Certain trade wastes may greatly decrease the rate of draining.
4. Chemicals, such as alum, help drainability when the sludge is poorly digested or has been stored too long, but are ineffective when sludge is gasifying freely.

THE LIPIDS OF SEWAGE SLUDGE

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Because of their origin, sewage solids probably contain a greater variety of lipoidal compounds than is found in any other biological material. It is to be expected, therefore, that the approximately complete extraction of the lipids from sewage sludge will present many difficulties.

The term lipids as used in this paper is intended to designate fatty acids, substances yielding fatty acids on hydrolysis, and other substances which are physically of a fat-like character, and which can be extracted with fat solvents from biological materials. The crude extracts which we have obtained from sewage sludge undoubtedly contain substances, e.g., tarry materials, which are not lipids; but, as the main part of the extracts is lipoidal in character, this term has been used as a suitable and convenient designation.

Ethyl ether is generally employed as the solvent for extraction of the lipids of plant and animal material and has long been used in the determination of the so-called "grease" of sewage solids. It has been shown by a number of investigators that ether does not remove all the lipids from biological materials, therefore various other solvents, alone or combined with one another, have been used to overcome the difficulty. Pre-treatment of the material, with various reagents such as acid or alkali, has been employed in order to improve the extraction. Sando (1) has given an excellent review of various procedures which have been used for the removal of the lipids of plant materials.

Saponification of the extracted residue, with subsequent acidification and extraction of the fatty acids, is usually employed in order to determine the efficiency of the extraction procedure. Saponification splits fatty acids away from other compounds with which they may be combined, such as carbohydrates, proteins and complex lipids, and also disintegrates material which may act mechanically to prevent penetration of the solvent and extraction of the lipids.

In the following experiments the efficiency of various solvents has been compared and some information regarding the character of the lipids in sewage solids has been obtained.

EXPERIMENTAL WORK

Samples: Sludges from Madison (6 samples), Milwaukee (1 sample), and Chicago (3 samples) have been analyzed as well as a sample of

TABLE I.—*Quantity of Material Extracted from Sludges by Different Fat Solvents*

No.	Material	Treatment	Madison Sludges				Milorganite	Milwaukee Activated
			Domestic		Packing house			
			No. 1	No. 2	No. 1	No. 2		
			%	%	%	%	%	%
1	Dried sludge	Petroleum ether	24.7	26.0	18.4*	27.8	5.6	6.5
2	Residue from 1	Saponified etc.	14.3	18.0	16.9	18.9	5.7	5.8
		Total	39.0	44.0	35.3	46.7	11.3	12.3
3	Dried sludge	Ethyl ether	23.6	Not determined	21.3	Not determined	Not determined	Not determined
4	Residue from 3	Saponified etc.	14.3	" "	13.4	" "	" "	" "
		Total	37.9		34.7			
5	Dried sludge	Isopropyl ether	31.1	" "	30.3	" "	" "	" "
6	Residue from 5	Saponified etc.	7.9	" "	8.9	" "	" "	" "
		Total	39.0		39.2			
7	Dried sludge	Chloroform	42.5	40.5	38.8†	46.0	9.6	10.3
8	Residue from 7	Saponified etc.	3.6	9.5	4.2	4.6	2.5	3.5
		Total	46.1	50.0	43.0	50.6	12.1	13.8

* Contained 0.3% N; 6.2% ash (Ca, 41.6%; P, 21.5; Fe, 6.3; Mg, 2).

† Contained 0.25% N; 8.5% ash (Ca, 44.2%; P, 12.8; Fe, 5.2; Mg, 2).

Milorganite. The latter is the trade name for dried Milwaukee activated sludge. All of the Madison and Chicago samples were fresh, settled sludges. Eight of these were taken from primary settling tanks, and the ninth (Chicago Calumet) was obtained by a collecting device placed in the settling compartment of an Imhoff tank.

Extractive Power of Certain Solvents.—About 5 gm. of solids were placed in a thimble and extracted in a Caldwell exxtractor with the solvent for 48 hours. All samples were run at least in duplicate, and in more than two-thirds of the analyses three or more replicates were made. The replicates usually checked to within 1 to 2 per cent. The data for four samples of Madison sludges and two of Milwaukee are given in Table I.

The general conclusion which may be drawn from the data is that chloroform extracts nearly twice as much material as does petroleum ether or ethyl ether; that isopropyl ether is a better solvent than either of the other ethers but still does not approach chloroform as an extracting agent. The two Madison sludges contained an extraordinarily large amount of chloroform-soluble material (about 40 per cent), while the Milwaukee samples contained about one-fourth as much. Likewise petroleum ether extracted about four times as much material in the Madison samples as in those from Milwaukee.

To determine whether all lipoidal material had been extracted, the procedure usually applied to animal tissues was employed. The residues were refluxed with 50 c.c. of 10 per cent alcoholic KOH for two hours, filtered, and washed with alcohol until the washings became neutral. The combined filtrate and washings were distilled in a vacuum to remove alcohol; water was added as the volume became small. The water solution was acidified and the liberated fatty acids were extracted with ethyl ether. After removal of the ether, the acids were dried and weighed. The data are given in Table I.

The results from the Madison sludges show that fatty acids equivalent to about 40 per cent of the total lipid were recovered from the petroleum ether and ethyl ether residues, about 20 per cent from the isopropyl ether insoluble material, and only about 10 per cent from the chloroform residues.

The figures for the residues from the Milwaukee samples, while smaller than those for the Madison samples, comprise a larger proportion of the total extract; in the case of petroleum ether about one-half and with chloroform about one-fourth of the total lipid remained in the residue after the first extraction.

A question naturally arises as to whether the high figures for the initial chloroform extract were due to the presence of non-lipid material. Some information on this point is obtained from the nitrogen and ash analyses. The petroleum ether and chloroform extracts are much alike in their content of nitrogen, which is low in both cases. They are also much alike in the percentage of ash and in the composition of the ash. The high percentage of calcium in both cases indicates that the extracts contained large quantities of calcium soaps and that chloroform is a much better solvent for such soaps than petroleum ether.

It was thought desirable therefore to determine the solubility of calcium soaps of both known and unknown fatty acids in the two solvents before making any further examination of the sludge lipids.

TABLE II.—*Extraction of Known Lipids*

No.	Sample	Petroleum Ether		Chloroform	
		Found	Calculated (*a*)	Found	Calculated (*a*)
		%	%	%	%
1	Ca stearate	0.0	—	1.6	—
2	Ca oleate	15.9	—	84.7	—
3	Ca stearate stearic acid (50 : 50)	52.7	50.0	51.8	50.8
4	Ca stearate-Ca oleate (50 : 50)	22.3 (*b*)	8.0	68.5 (*c*)	43.2
5	Ca soap (toilet)	17.0	5.7 (*d*)	97.3	31.5
6	Mg soap (toilet)	81.4	—	93.0	—
7	Lard, beeswax or car grease	100	—	100	—

(*a*) The calculations are made by assuming that the solubilities of calcium stearate and calcium oleate remain unchanged in mixtures—an assumption which is shown by the data to be unwarranted.

(*b*) Based on the iodine number, this extract consisted of 76.8 per cent oleate and 23.2 per cent stearate; *i.e.*, 34.2 per cent of the oleate and 10.4 per cent of the stearate had been extracted.

(*c*) Here also the iodine number showed that a very large proportion of the stearate had been extracted. The extract consisted of 63.5 per cent oleate and 36.5 per cent stearate. Therefore 87 per cent of the oleate and 51 per cent of the stearate had been extracted.

(*d*) Contained 64 per cent saturated fatty acids and 36 per cent unsaturated fatty acids. The extractability of the calcium soaps of the saturated acids is assumed to be the value found for calcium stearate and that of the calcium soaps of the unsaturated acids to be the figure found for calcium oleate.

Extractability of Soaps by Petroleum Ether and Chloroform.—The soaps were ground in a mortar with clean Ottawa sand, transferred to a thimble and extracted for 24 hours in a Caldwell extractor with either petroleum ether or chloroform. The figures in Table II express the percentage of the sample extracted by the given solvent.

The data show that calcium stearate is practically insoluble in both solvents and that calcium oleate is much more soluble in chloroform than in petroleum ether. Comparison of Columns 3 and 5 makes it evident that both calcium and magnesium soaps are more readily extracted by chloroform than by petroleum ether. In the case of the mixed calcium soaps made from toilet soap the difference is very striking; more than five times as much material was extracted by chloroform as by petroleum ether. Magnesium soaps, on the other hand, proved to be readily extracted by both solvents.

It is well known that one lipid may influence the solubility of another lipid. It was thought possible that mixing free fatty acids or a soluble calcium soap such as calcium oleate with an insoluble calcium soap might affect the solubility of the latter. Stearic acid, when mixed with calcium stearate, did not change the solubility of the latter, but calcium oleate did.

Mixing the two soaps doubled the quantity of calcium oleate extracted by petroleum ether and increased that of calcium stearate from zero to about 10 per cent. With chloroform the effect of mixing the soaps on the solubility of calcium stearate was even more marked. More than 40 per cent of the stearate in the mixture was extracted along with the oleate, whereas without the oleate less than 2 per cent of the stearate was removed.

Additional Data on Comparative Efficiencies of Petroleum Ether and Chloroform.—The A. P. H. A. (2) methods recommend that sewage solids be acidified and extracted with petroleum ether so as to include the fatty acids of soaps in the extract. The general procedure which was used to acquire the data of Table III consisted of an initial extraction with the solvent and then a second extraction after the solids had been acidified.

Considerable quantities of soap fatty acid remained in the sludge solids previously extracted with petroleum ether (1.9–14.1 per cent). The solids, after acidification and extraction with petroleum ether, still contained lipid material which could be extracted with chloroform. The amount ranged from 12 per cent of the total for Madison domestic sludge to over 40 per cent for the Calumet sample. It appears that, even with acidification, petroleum ether does not remove all of the fat-like substances.

In contrast to the large quantity of lipids obtained from the petroleum ether residues, but little additional material was obtained from most of the samples by acidifying and re-extracting the chloroform residues. The Calumet sample, however, yielded a considerable quantity in the second extraction; approximately 25 per cent of the total.

Some information regarding the composition of the material extracted after acidification was obtained by titrating the extract with alcoholic KOH to the phenolphthalein endpoint. Expressed as stearic acid the free acid of the extracts ranged from 61 to 95 per cent of the total. As would be expected, a higher percentage of the petroleum ether extract was accounted for by this procedure than was the case with the chloroform. The latter contained a great deal of black material which was probably not fatty acids.

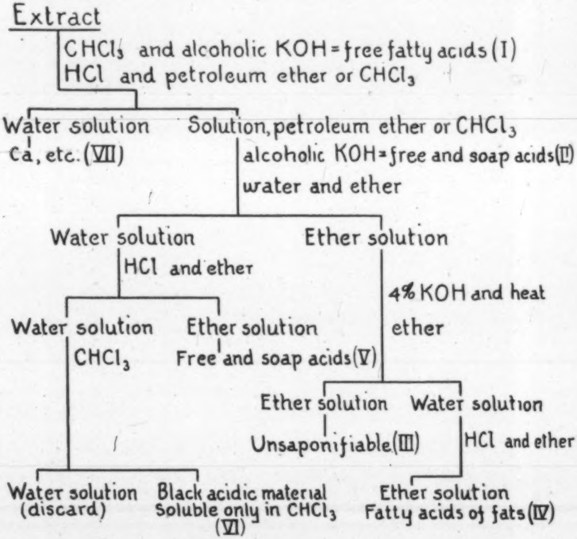
TABLE III.—*Efficiency of Solvents as Determined by Acidification and Re-extraction*

No.	Material	Solvent	Madison*		Chicago*		
			Domestic No. 3	Packing-house No. 3	North side	West side	Calumet
			%	%	%	%	%
1	Dried sludge	Petroleum ether	19.6	8.7	16.9	11.0	4.4
2	Residue from 1 acidified	Petroleum ether	12.3	14.1	3.7	8.1	1.9
			(91)	(91)	(86)	—	(78)
3	Residue from 2	Chloroform	4.4	8.2	3.4	—	4.3
			(61)	(70)	(85)		
	Total, 1–3		36.3	31.0	24.0	—	10.6
1	Dried sludge	Chloroform	43.3	32.2	25.5	25.4	11.1
2	Residue from 4 acidified	Chloroform	1.1	3.4	0.7	1.7	3.5
			(82)	(88)	(71)	(64)	(95)
	Total, 1–2		44.4	35.6	26.2	27.1	14.6

* The figures in parentheses give the fatty acid content, calculated as stearic, of the fraction.

Composition of Lipoidal Extracts.—The nature of the materials extracted directly from the untreated sludge by petroleum ether and by chloroform was investigated, and, after several fractionation procedures had been tried, that outlined in Figure 1 was adopted as most satisfactory.

The extract was dissolved in chloroform, titrated with alcoholic KOH and the acid equivalent of this titration expressed as stearic acid (I). After the solvents had been evaporated, an excess of 1 N. HCl was allowed to react with the extract at 80° C. for one hour in order to liberate the acids from the potassium and calcium soaps. After the mixture had cooled, it was extracted with petroleum ether if this solvent had been used in the original extraction or with chloroform if the latter had been used for the first extraction. The extract was titrated with alcoholic KOH and the stearic acid equivalent of this titration was taken


Extract
CHCl3 and alcoholic KOH = free fatty acids (I)
HCl and petroleum ether or CHCl3
Water solution
Ca, etc. (VII)
Solution, petroleum ether or CHCl3
alcoholic KOH = free and soap acids (II)
water and ether
Water solution
HCl and ether
Ether solution
4% KOH and heat
ether
Water solution
CHCl3
Ether solution
Free and soap acids (V)
Ether solution
Unsaponifiable (III)
Water solution
HCl and ether
Water solution (discard)
Black acidic material Soluble only in CHCl3 (VI)
Ether solution
Fatty acids of fats (IV)

Note: The numbers (I) to (VII) correspond to the fractions given in Table IV

FIG. 1.—Fractionation of lipid extracts.

to represent the free and soap fatty acids (II). After the solvents were evaporated, water was added, and fat and unsaponifiable matter were removed with petroleum ether. After this extract had been saponified, unsaponifiable matter was separated with petroleum ether (III), and fatty acids recovered after acidification by extraction with ether (IV). The potassium soaps and other water soluble material were acidified and extracted with petroleum ether. This extract contained the free fatty acids and the fatty acids of the soaps of the original extract (V). These acids were dissolved in chloroform and titrated with alcoholic KOH, and the neutral equivalent of the combined acids was calculated. The acidified water solution, especially that from a chloroform extract, contained

TABLE IV.—*Percentage Composition of Lipoidal Material*

No. in Figure 1	Fraction	Madison domestic sample 3		Madison packing sample 3		Chicago North Side		Chicago West Side		Chicago Calumet	
		P.E. extract	$CHCl_3$ extract	P.E. extract	$CHCl_3$ extract	P.E. extract	$CHCl_3$ extract	P.E. extract	$CHCl_3$ extract	P.E. extract	$CHCl_3$ extract
I	Free fatty acid	26.3	33.3	78.2	45.4	31.8	40.7	28.6	28.8	32.0	38.7
*	Soap fatty acid	33.7	30.7	3.5	34.2	24.7	18.1	10.3	25.1	7.4	—
IV	Fat fatty acid	9.5	1.4	7.2	2.1	2.0	2.4	3.7	3.7	8.6	13.5
III	Unsaponifiable	3.4				4.5	1.2	12.8	12.8	31.0	16.9
VI	Soluble only in $CHCl_3$	10.6	15.9	—	14.9	—	9.0	—	6.4	—	10.6
	Ash	11.0	10.9	—	10.2	14.1	21.5	12.9	18.1	12.1	20.3
	Total	94.5	92.2	—	106.8	—	92.9	—	94.9	—	—
VII	Calcium in ash	4.8	4.9	—	5.1	4.1	4.2	1.6	3.1	1.0	1.8
	Neut. equiv. of free and soap acids	284	271**	291	295	368	367	497**	442	435	—

* Figures in this line were obtained by subtracting the value for free fatty acid (I) from that for free and soap fatty acid (II).

** Calculated from first titration figure of free and soap acids (II) and weight of these after removal of fat and unsaponifiable (V). The other equivalents were obtained by direct titration of the weighed acids (V) in Figure 1.

a black acidic substance which could only be extracted with chloroform (VI).

The data obtained by this method of fractionation are given in Table IV and appear to warrant the following conclusions:

1. Free fatty acid constitutes, in all but one case, the largest fraction of the extracts, regardless of whether these were obtained by means of petroleum ether or chloroform. However, not all of the fatty acid contained in the sludge is extracted by petroleum ether. An example will make this clearer. From Tables III and IV the weight of free fatty acids extracted from 100 gm. of sludge may be calculated. In case of the Madison domestic sample this amounts to 5.2 gm. for petroleum ether and 14.4 gm. for chloroform. Thus there remained in the residue from the petroleum ether extraction 9.2 gm. of free fatty acid—nearly twice the amount extracted.

Similar calculations for the other samples show that usually less than one-half, and in one (the Calumet sample) only one-third, of the free acid in the sludge was extracted by petroleum ether. More data will be presented later regarding the nature of the free acid of the sludges.

2. Soap was the next largest constituent of the extracts. In one case the soap acids exceeded the free acids and in several others almost equalled them. In seven out of nine cases the free and soap acids accounted for 55 per cent or more of the total extract. In one case (Madison packing house) the combined acids made up 80 per cent of the extract. The free and soap acids appear, from their neutral equivalents, to be of peculiar character. Only in the case of the Madison samples do the neutral equivalents fall within the range of the common fatty acids, oleic, etc. It is doubtful that the high figures for the other samples indicate the presence of fatty acids having such high molecular weights; a more reasonable conclusion is the presence of non-acidic impurities which give to the material a high neutral equivalent.

3. Hydrolyzable fat and unsaponifiable matter make up 10 per cent or less of the extract of the Madison samples and the North Side Chicago sample, but in the extracts of the other two Chicago samples these constituents form a considerable part.

4. The fraction designated as "soluble only in $CHCl_3$" was a black, tar-like material with rather acidic properties. It has not been investigated further and may not be lipoidal in character.

5. The ash content of the extracts was high, probably because of the high percentage of soap contained in the extracts. In the first three samples the ash consisted largely of calcium but in the last two, calcium made up only 10–15 per cent of the ash.

Nature of the Free Acids in Sludge.—The fact that petroleum ether extracted only from one-third to one-half of the free acid from the sludges seemed to make necessary some further investigation. For this purpose Sample No. 3 of Madison packing-house sludge was chosen. That the insolubility of the acids was not due to encrusting materials was proved by depositing the chloroform extract on asbestos and extracting it with petroleum ether. The results were about the same as with the sludge itself; from one-half to two-thirds of the acids proved unextractable.

An attempt to remove the acids by converting them into their potassium soaps, washing out the potassium soaps with hot water, and recovering the acids from the water solution, was only partly successful. Although the hot water extracted a weight of material equivalent to 90 per cent or more of the free acids in the chloroform extract, the weight of free acids recovered from the hot water extract never accounted for more than 30 per cent of those contained in the chloroform extract. Of the extracted acids about one-half were insoluble in petroleum ether but soluble in chloroform. Those soluble in petroleum ether seemed to be saturated fatty acids and were comparatively free from coloring matter. Their neutral equivalents were in the neighborhood of 290. The acids soluble only in chloroform contained a good deal of black material which made the determination of the neutral equivalent unreliable. Because of their unusual solubilities these acids were purified through the preparation and distillation of their methyl esters.

In order to bring about esterification the crude material, 5.66 g. was refluxed ten hours with 100 c.c. methyl alcohol and 3.8 c.c. of concentrated sulfuric acid. The bulk of the alcohol was then removed, water added, and the esters extracted with ether. The ether solution was washed with water, the ether removed, and the esters distilled at 3 mm. pressure. The distillate, b. pt. 120–210° C., weighed 2.60 g., while 1.47 g. of a tarry residue remained in the flask.

The distilled esters were saponified with methyl alcoholic potassium hydroxide, and the free acid obtained by shaking out with ether after acidification. The acid was dried under CO_2 at 100°, and on cooling set to a light-colored, waxy solid. It seemed to be insoluble in petroleum ether, but was soluble in chloroform. Addition of petroleum ether to the chloroform solution caused a distinct cloudiness. Two determinations of the neutral equivalent gave 149.7 and 148.2.

In order to determine more accurately the solubility of the material in petroleum ether, 1.366 g. was extracted several times with this solvent After evaporation of the extract 0.510 g. or 37.4 per cent of the original weight was found to have been dissolved. The neutral equivalent of this petroleum ether soluble fraction was 196. The insoluble portion, which had a neutral equivalent of 134, was tested for the presence of hydroxy acids by determining the acetyl value according to the improved method of West, Hoagland and Curtis (3). The acetyl value, which is defined by the above authors as the milligrams of acetyl (CH_3CO) taken up by one gram of the substance, was found to be 24.0. The theoretical acetyl value of a monohydroxy acid of molecular weight 134 is 321. Consequently the above result indicates that not more than $24/321 \cdot 100 = 7.5$ per cent of such an acid could be present in the petroleum ether insoluble fraction.

It is very probable, therefore, that the bulk of this fraction consisted of dicarboxylic acids of the azelaic type, which might easily be produced in the sludge through oxidative degradation of unsaturated fatty acids, and which are known to be insoluble in petroleum ether. The petroleum ether soluble fraction on the other hand probably consisted largely of lower fatty acids such as pelargonic, plus a certain amount of unchanged fatty acids. To determine with certainty the nature of these acids would of course require the use of larger quantities of material and an exact characterization, a problem which was considered to be beyond the scope of this investigation.

SUMMARY

Eleven samples of sludge from six different sewage plants (Madison, Milwaukee, Chicago) were investigated with respect to the amount and kind of lipids contained therein.

Four solvents were compared with respect to the quantity of lipid extracted from the sludges. Chloroform extracted the largest and petroleum ether the smallest percentage of material; chloroform extracted approximately twice as much material as did petroleum ether. Even with acidification of the sludge petroleum ether removed less material than chloroform did without acidification. On the basis of these data it is suggested that the use of chloroform as a solvent in the routine analysis of sludges should be considered.

Fractionation of the petroleum ether and chloroform extracts gave the following percentage distribution: free acid, 26–78; soap fatty acid, 4–34; fat fatty acid, 2–14; unsaponifiable matter, 1–31; soluble only in chloroform, 6–19; ash, 11–22.

The free acid of the chloroform extract contained both petroleum ether soluble and insoluble acids. The former had the properties of the common higher fatty acids, but the latter were of different character. Some of the insoluble acids were purified through their methyl esters and again separated into petroleum ether soluble and insoluble fractions. The neutral equivalents of these two fractions were 196 and 134 re-

spectively. A low acetyl value (24.0) indicated the presence of a small amount of hydroxy acid in the insoluble fraction. The remainder is tentatively assumed to consist in part of dibasic fatty acids, *e.g.*, of the azelaic type.

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EFFECT OF CHLORINE DOSAGE UPON THE PERCENTAGE REDUCTION OF B. COLI *

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The amount of chlorine necessary to react for 10 minutes with sewage matter is affected by the quality and nature of the sewage constituents. If the sewage is strong a larger amount of chlorine will be required to satisfy the chlorine demand, due to the greater amount of organic and inorganic materials absorbing or reacting with chlorine. Likewise, if the sewage is stale, more matter will be in solution and suspension and, hence, more amenable to reaction with chlorine. As sewage ages the chlorine demand again decreases, due to change of substances present to simpler compounds with no chlorine demand.

It has been shown previously (1) that contact time affects the percentage bacterial reductions, increased contact time producing greater bacterial removals. Chlorine disappears rapidly upon addition of quantities below the total chlorine demand. This led us to suppose that chloro-products (chloramines, chloro-amino acids and chloro-organic acids) were formed upon chlorinating sewage, and that these chloro-products exerted a toxic effect upon the organisms.

It has not been shown whether approximately the same percentage bacterial removals can be accomplished if sewages with high and low chlorine demands are partially satisfied with chlorine. Just what percentage of the chlorine demand satisfaction is necessary to bring about a percentage B. coli reduction greater than 90? Is it possible to reduce the amount of chlorine that at present seems necessary? Approximately how much chlorine, regardless of the chlorine demand, must be added to produce the necessary B. coli reductions? Is a 99.9 per cent B. coli kill necessary or would a 90 per cent reduction serve the purpose in many cases? An attempt will be made to answer these questions in this paper.

Methods

A study of the effect of chlorine demand variations upon the percentage B. coli reduction for given percentage chlorine demand satisfactions was undertaken in the following manner: Chlorine demands of strong undiluted sewage and the same sewage diluted 1:2 and 1:4 with distilled water were determined. Amounts of chlorine equal to

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0, 20 and 40 per cent of the chlorine demand were added to the diluted and undiluted sewages. The chlorine was left in contact for 15 minutes with the sewages. After this time an excess of sodium thiosulphate was added to make sure that no available chlorine was left. The numbers of B. coli were determined by the ferrocyanide-citrate agar method as devised by Noble and Tonney (2).

Other results were obtained by satisfying the chlorine demand to the extent of 10 and 20 per cent and maintaining 15, 20, 25 and 30-minute contact periods. The sewages in this series of experiments were not diluted for the purpose of altering the chlorine demand. The chlorine demands varied with the original samples as collected.

RESULTS

The effects of chlorine demand variations upon the percentage B. coli reduction for 20 and 40 per cent chlorine demand satisfaction are given in Table I. No matter what percentage of demand is satisfied the sewage with a lower chlorine demand gives lower percentage B. coli reductions than the sewages with higher chlorine demands. The effect of chlorine demand variations on kill is less pronounced, although discernible, when the percentage satisfaction is increased to 40 and above.

Where the sewage required 17.4 p.p.m. chlorine to satisfy the demand, roughly 6 and 8 times as many organisms must be killed as in the case of sewages possessing chlorine demands of 8.7 p.p.m. and 4.35 p.p.m. respectively to obtain the same percentage of kill.

TABLE I.—*Effect of Chlorine Demand Variation upon the Percentage B. coli Reduction (Contact Time 15 Min.)*

Cl_2 Demand of Sewage	Cl_2 Added		% Chlorine Demand Satisfied		
	20%	40%	0	20	40
P.p.m.	P.p.m.	P.p.m.	Per cc.	% Red.	% Red.
17.4	3.5	6.8	524,000	98.4	99.9
8.7	1.7	3.5	90,000	93.2	98.7
4.35	0.8	1.7	63,000	60.8	96.4

Plotting the results (Fig. 1) of partial chlorination of sewages with different chlorine demands shows that the curves have the same general trend, except that the critical point occurs in low chlorine demands (3 to 4 p.p.m.) with a 40 per cent satisfaction and in high chlorine demand with a satisfaction of 20 per cent (10 p.p.m.). These results indicate that the same amount of chlorine added to sewages of different chlorine demands accomplishes the same percentage B. coli removal.

If, from the graph, we calculate the amount of chlorine necessary to effect a 90 per cent B. coli kill after a 15 minute reaction time, we find that approximately 1.7 p.p.m. must be added when the chlorine demand is satisfied to the extent of 20 and 40 per cent respectively. The quantity of chlorine added to obtain results is therefore not in proportion to the chlorine demand satisfied. This accounts for the fact that sewages of different chlorine demand give the same kill when the same quantity of chlorine is added (see Fig. 1). The free or residual chlorine would thus play a very important part in the effectiveness of chlorination.

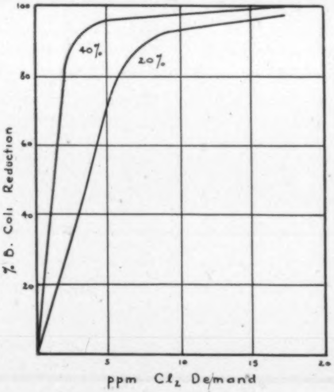

FIG. 1.—Effect of chlorine demand upon the per cent B. coli reduction for given per cent chlorine demand satisfaction.

It has been shown previously (1) that there is a relation between contact time and bacterial kill. There is also a relation between percentage B. coli reduction and percentage chlorine demand satisfaction. Again, there is a relation between the degree of chlorination and contact time. With a series of sewages having chlorine demands (4.8, 6.3, 7.0, 7.9, 8.5, 10.0, 13.5, 14.2 and 15.0 p.p.m.) the effect of contact time was determined when only 10 and 20 per cent of the respective chlorine demands were satisfied. It was shown that (a) a greater percentage B. coli reduction occurred with increasing contact time and (b) greater reduction resulted with the same chlorine demand satisfaction when the chlorine demand increased. The average results on the effect of time on B. coli reduction for 10 and 20 per cent satisfaction are shown in Fig. 2. It can be seen that 10 per cent chlorine demand satisfaction produced the same results in 30 minutes as 20 per cent satisfaction in 15 minutes.

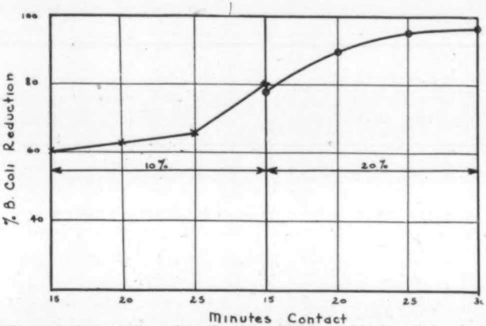

FIG. 2.—Effect of time on B. coli reduction with low chlorine demand satisfaction.

Disregarding contact time, the effect of increased demand (increasing dosage added but constant chlorine demand satisfied) is shown in Fig. 3. With the same proportion of chlorine demand satisfied the percentage kill increases rapidly with increased dosage. It is clear, therefore, that the chlorine demand satisfaction has no definite relation to kill of B. coli, but that the dosage or quantity of chlorine added is of real importance.

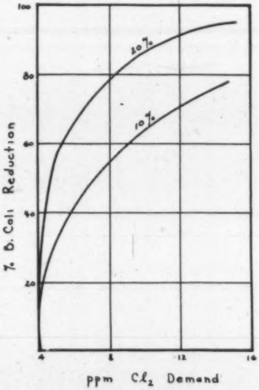

FIG. 3.—Effect of increasing chlorine demand upon B. coli reduction (low per cent chlorine satisfied).

From the results submitted it is interesting to note that the greatest bactericidal efficiency occurs when only 10 per cent of the chlorine demand is satisfied, and that the efficiency decreases as the percentage satisfaction increases.

Discussion

When sewage is partially chlorinated the percentage B. coli reduction (with constant contact periods of 15 to 30 minutes) varies with the increase of chlorine added, but when the chlorine demand of the sewage is satisfied up to 60 per cent and above, the variations are negligible. With these higher percentages of chlorine demand satisfactions the percentage B. coli reductions do not vary with the chlorine demand of the sewage, as is the case when 50 per cent or less of the chlorine demand is satisfied. The relationship between low and high percentage B. coli reduction and small and large chlorine demands of sewages seems to indicate that the amount of chlorine applied, and not the magnitude of the chlorine demand, determines the extent to which the bacteria are destroyed. In other words, if 1 p.p.m. chlorine is added to a sewage with a chlorine demand of 10 p.p.m. and 2 p.p.m. is added to a sewage with a chlorine demand of 20 p.p.m., a greater kill can be expected in the latter case. This holds for contact times up to at least 30 minutes. The efficiency of the chlorine is greatest when a low percentage of the chlorine demand is satisfied, and the bactericidal efficiency decreases as the percentage chlorine demand satisfaction increases. This is due to the fact that the chlorine resistant substances increase relatively rapidly as the chlorine dosage increases. When chlorine is added the chlorine reacts or combines with the substances in solution and suspension. The action is so rapid that those materials and particles in the immediate neighborhood of the chlorine are satisfied immediately. The particles (bacteria included) which are a greater distance from the chlorine are reached with difficulty or not at all.

Chlorine Penetration

The results recorded in this paper were secured with efficient and uniform chlorine distribution. The effects of brief vs. prolonged mixing will be discussed in detail in a subsequent paper, together with other physical factors. When the initial mixing is thorough, the chlorine penetration is extremely rapid. When the rate of chlorine consumption is compared with the rate of bacterial reduction the plotted results can be interchanged.

An example of the rate of kill with contact times varying from 0.25 to 10 minutes and 50 per cent of the chlorine demand satisfied is shown in Fig. 4. The original chlorine demand of these sewages was 7.3 and 12 p.p.m., and the count was 950,000 B. coli per c.c. The reaction was stopped at the pre-determined times with an excess of sodium thiosulphate and counts were made immediately. With a chlorine demand satisfaction of 50 per cent and 15 seconds contact time, about 90 per cent of the B. coli were killed and 95 per cent after 10 minutes. If the time required for chlorine consumption is compared with the velocity of kill the relationship becomes apparent. An example of fresh and stale sewage (5 days old) is shown in Fig. 5. In the case of the stale sewage 95 per cent of the chlorine demand was satisfied within ½ minute and 90 per cent of the chlorine demand of the fresh sewage in the same time.

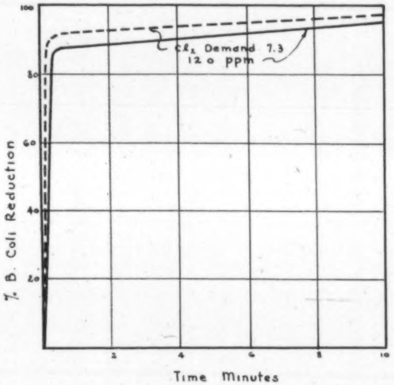

FIG. 4.—Rate of B. coli kill with 50 per cent chlorine demand satisfaction and increasing contact time.

We have shown that about 30 per cent B. coli reduction results with a 20 per cent chlorine demand satisfaction and 2½-minute contact period, and that 90 per cent kill results with a 30-minute contact time. The results also show that with 50 per cent chlorine satisfaction the kill is about 90 per cent in 15 seconds contact time. Keeping in mind that the rate of chlorine absorption does not vary with the sewage, but only the quantity required, we may conclude that (1) the chlorine exerts its toxic effect directly (as primary chlorine) and (2) indirectly (as chlorinated organic products). Enslow, Hale and Carpenter (3) state that at least 90 per cent of the total quantity of chlorine applied disappears immediately. Their results were obtained with quantities of chlorine at least sufficient to satisfy the chlorine demand. It is clear from our results that this percentage chlorine consumption holds irrespective of the quantity of chlorine added. These facts explain the reason why (1) the percentage B. coli kill varies with the amount of active chlorine present, (2) why, with partial chlorination, a relatively large kill can be secured, (3) contact time is important only with poor immediate distribution of the chlorine, (4) contact time becomes increasingly important with sub-chlorination.

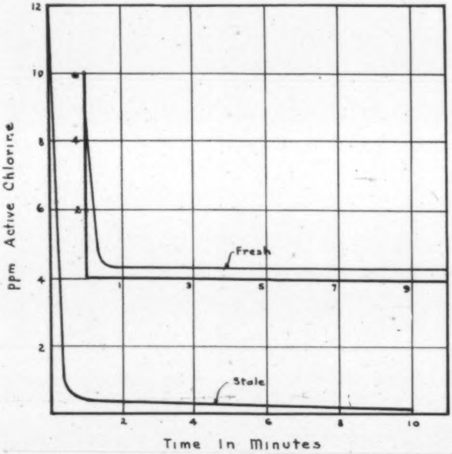

FIG. 5.—Time required for chlorine consumption in fresh and stale sewage.

In view of our results it appears that for the purpose of destroying 90 per cent of the B. coli, sewage can be chlorinated on a fixed dosage basis, and with a sewage of an average chlorine demand of 10 p.p.m., an average B. coli reduction of 97 per cent can be obtained in 30 minutes contact time with 20 per cent chlorine demand satisfaction; 95 per cent B. coli reduction with 10 minutes contact time and 50 per cent chlorine demand satisfied; and 99 per cent B. coli reduction with 60 per cent chlorine demand satisfaction and 15 minutes contact time.

It is obvious that partial chlorination with a fixed chlorine dosage may be practiced in a number of cases. Unsatisfactory results obtained in practice can be ascribed to (1) insufficient spontaneous mixing of chlorine and sewage and (2) insufficient contact time. It appears that immediate efficient distribution of the chlorine is more important than contact time, and that the latter can be regarded more in the nature of a safeguard. When the chlorine concentration is increased (the percentage chlorine demand satisfaction) the contact time can be reduced.

The chlorine demand of fresh sewage is less than that of stale sewage. It follows therefore that with equal contact times and equal distribution, a greater percentage B. coli reduction should be obtained when stale sewage is chlorinated, because the quantity of chlorine required is greater. The greater quantity of chlorine results in more initial active chlorine and larger quantities of subsequent chlorine products, which act more slowly. However, this effect is practically lost when sewage is chlorinated to 50 per cent or more of its demand and the kill might even be less in stale sewage if the contact time were not increased. It also follows that chlorine reduction can be practiced with better success when stale sewage is treated and longer contact times are available because of the larger quantities of chloro-products formed.

It has been shown previously (1) that complex organic (nitrogenous) compounds possess chlorine demands which vary quantitatively in proportion to the increased concentration and type of material present. The chloro-products formed, such as chloro-peptones and chloro-proteins, are neither inhibitory to growth of bacteria nor have germicidal properties. Sewages containing trade wastes with proteinaceous substances present require more chlorine, while additional contact time has little or no effect. In such cases immediate distribution is the most important factor and the possibility of reducing the chlorine dosage is less.

When screened, settled or completely treated sewage is discharged into watercourses used for water supply and recreation, complete chlorination is necessary. The same will hold in those instances where shellfish must be protected. There are, however, many cases where it would seem that a 90 to 95 per cent reduction of B. coli is sufficient. In instances where large volumes of diluting water are available chlorination is not practiced at present, because the cost is too high. Chlorination of sewage in sewers to prevent or retard H_2S production is again frequently foregone on account of cost. Partial chlorination up to 50 per cent of the chlorine demand might be sufficient and all that is required.

SUMMARY

Sewages were partly chlorinated to the extent of 20, 40 and 50 per cent of the initial chlorine demand. The rates of B. coli reduction were determined and also the time required for chlorine consumption in fresh and stale sewages. Partially chlorinated sewages were subjected to varying contact periods.

The chlorine consumption rate was shown to be instantaneous as was also the B. coli kill in both fresh and stale sewages. Fifty per cent of chlorine demand satisfaction will bring about a 90 per cent B. coli kill in fifteen seconds or less, if mixing is thorough.

The percentage B. coli reduction depends upon the amount of chlorine added and not upon the per cent of the chlorine demand satisfied.

Thus with constant contact time the percentage B. coli reduction is greater in strong sewages, containing more chlorine-absorbing substances, than in dilute sewages. This effect is most marked under 50 per cent of chlorine satisfaction. In any given sewage, the greater the percentage of the demand satisfied, the greater the B. coli kill.

The total germicidal activity of the added chlorine is not expended immediately. That which is taken up by certain substances remains slowly active for almost an hour after chlorine application. Small amounts of chlorine may be as effective as larger amounts when allowed to act for shorter periods. Contact time, therefore, is necessary for utilization of the germicidal properties of these substances and is also useful as a safety factor in chlorinating to any fractional amount.

In sewage containing trade waste of a nitrogenous character, more chlorine is required to satisfy the demand. However, in the case of these substances, no effective quantities of germicidal "chloro" products are formed and no secondary kill takes place.

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DISPOSAL OF GARBAGE WITH SEWAGE SLUDGE[1]

By H. E. Babbitt

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Garbage digestion with sewage sludge is no new idea. It was conceived the first time some organic matter fell into a cesspool. It was mentioned by Moore in his book on sanitary engineering, as having been practiced at Southampton, England, as long ago as 1885. A search of sewage works literature fails to find a mention of the practice again until quite recently. No credit is claimed by any of the present-day writers or thinkers on the subject for originality in the thought. It is interesting to note that articles of value have appeared recently in sewage works periodicals, principally in this JOURNAL, and that the practice of disposing of garbage with sewage is attracting some attention.

Before the installation of the water carriage system for the collection of fecal matter, dry methods of collection were used which included the privy, the ordure pit, and the can system. It was probably discovered before the dawn of history that fecal matter deposited in a water course would float away with the water. Some ages later sewers were established to utilize this phenomenon. The process was found so successful that it is now the established practice for the collection of fecal matter in modern urban centers. If the process can be successful with fecal matter, why not with garbage?

Some wag once defined a sewer as a long tube into one end of which the general public deposited that which they did not want and at the other end of which was a group of fanatical scientists trying to undo that which had been done. The attempt to separate the solids from the liquids issuing from the outfall sewer is now the principal effort of the sewage plant operator. It sometimes occasions considerable trouble and expense to accomplish this. What is going to happen if some hare-brained idiot persuades the public to put their banana peels, their coffee grounds, and all other undesirable organic matter into the sewer? To the sewage works operator, overloaded with his present troubles, the idea may constitute a nightmare.

To the householder the idea appeals at once. How convenient to have a fixture down which all of the garbage can be dropped as easily, as conveniently, and with as great cleanliness as the present method of getting rid of fecal matter. The smelly garbage wagon is done away with; the discord with the janitor over the garbage pail can be forgotten; there will be no necessity to roll the garbage can to the curb on Monday morning. All of these chores are done away with by the proposed process.

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[1] Presented at the Seventh Annual Convention of the Central States Sewage Works Association, Fond du Lac, Wisconsin, Sept. 28, 1934.

And what of the municipal official? What will be his attitude towards the proposal? If the problem of the incinerator, the reduction plant, the hog farm can be loaded on to the sewage plant operator, not only may the city exchequer be relieved of the load but there will be freedom from the complaints concerning the smell of the garbage plant; the dirty wagons; and the thousand and one other difficulties which arise from the collection and disposal of garbage. It seems almost like collecting a dozen problems and concentrating them upon the shoulders of an already heavily burdened branch of the government—the sewage plant operator. The question is, can he take it?

That is the question implied by the title of this paper. We at the University of Illinois, among others, are attempting to find an answer. If he can, it means greater accomplishments, greater worth, and, possibly, more jobs.

The title of this article is really in the form of a question, if one could read between the lines. The disposal of garbage into sewers and into sewage treatment plants is not an assured success; in fact, it is still open to question as to whether or not it is even possible.

Before the garbage reaches the sewage treatment plant there are many questions of an engineering and hydraulic nature which must be answered. First of all, the idea that the householder will ever be able to dump his garbage directly into the sewer is probably impractical because even though the sewage treatment plant could handle it, the sewers probably could not. The solid particles, bones, tin cans, other forms of containers, insoluble materials, etc., would quickly clog the sewers. No self-respecting sewer superintendent would, for a minute, countenance the proposal to dump garbage indiscriminately into the sewer. Trouble would be created in the house sewer before the material had reached the common sewer. Practical sewer men would soon put a stop to any such wild idea which should be credited only to fanatical researchers or college professors looking for new worlds to conquer or levers with which to push out the walls of knowledge.

Unfortunately dreamers, like fools, are born every minute, or even more frequently, and the garbage digestion dreamer sticks to his vision and points to the fact that the vision is endorsed by practical experience on a working scale. The dreamer admits that our present sewer systems are incapable of conveying untreated household garbage. This difficulty might be overcome in the future by designing sewers which will convey untreated household garbage; but who, today, can be interested in such chimerical dreams for the future? Very well then, instead of dumping untreated garbage directly into the sewer at the house, for it is admittedly impractical, it is possible to carry the garbage to a central point where it is ground into fine particles and dumped into a main sewer in which there is a large volume of flow. This is a condition which would be possible in most large cities provided with adequate sewerage facilities. The sewer can then carry the ground garbage to the point of final disposal. The relative cost of the installation of many garbage grinding centers might be, and probably would be, less than the cost of the installation of a large incinerator, a reduction plant, or a hog farm, for the disposal of garbage.

In the large cities the problem, therefore, rests between the economic advantage of the maintenance of garbage grinding centers and the added cost of treatment at the sewage disposal plant, compared with the cost of incineration or whatever method of disposal is practiced at present.

In the small cities, the collection of the garbage will have to continue as at present and the garbage will have either to be hauled directly to the disposal plant, as at present, or possibly ground and dumped into the sewer at some point nearer to the center of population of the community. Here again enters the question of relative economy.

Relative Quantities

Average daily garbage production per capita varies within the confines of any one city with the season, the economic conditions, and other factors. It is affected in various cities by their location, their population both in number and characteristics, and other factors. So far as the disposal of garbage with sewage sludge is concerned we know that the maximum daily garbage load per capita may reach figures relatively high compared with an average of one-half pound of garbage per capita per day. This basic figure will be adopted for convenience in estimating the possibilities of the process. Likewise a conservative figure of 80 gallons of sewage per capita per day will be assumed. In this type of problem the higher the rate of garbage production and the lower the rate of sewage flow assumed, the more conservative are the findings of the study.

If a sewage treatment plant is to take the full load of garbage from a city it must, therefore, take 6,250 pounds of garbage for every million gallons of sewage passing through the plant; or approximately three tons. Reports of fresh sludge produced by the plain sedimentation of raw sewage vary widely. Metcalf and Eddy, in *American Sewerage Practice,* Vol. III, page 467, 1915, report about 12 cu. yd. of fresh sludge per million gallons, whereas 162 cu. yd. per million gallons are reported at New Britain, Conn., in *Engineering Contracting,* Vol. 57;

page 35, 1922. The volume of raw garbage to be cared for, in relation to the volume of sludge can, therefore, be expected to vary greatly. The ratio of garbage to sludge may vary between 0.2 and 2.0.

From these approximate, hypothetical considerations it would seem that the load of garbage solids might be expected to exceed greatly the load of sewage solids. It might develop, therefore, that the digestion of garbage solids in sewage treatment plants would care for only a part of the garbage load; or might be practical merely to diminish the size of the garbage incinerator; or to take care of the peak load of the final method of garbage disposal. The glowing possibilities for caring for all of the garbage of a city in the sewage treatment plant begin to dim somewhat, but the hope is not entirely extinguished.

PURPOSE OF MIXING GARBAGE WITH SEWAGE

One purpose of mixing garbage with sewage is to secure the advantages of the water carriage of the garbage to the point of final disposal. The probability that this can be done successfully, provided the garbage is ground before it is cast into the sewer, is great. Hydraulic experiments to prove this can be made relatively inexpensively, and the experience in Baltimore can be cited to prove its practicability.

Biologically the advantages of mixing garbage with sewage would be to seed the garbage with organisms which could expedite the digestion, hydrolysis, and gasification of the garbage solids. Few data, hypothetical or otherwise, are available on which to base any definite hope of failure or success in such an endeavor. The Beccari system of garbage disposal accomplishes digestion of the garbage by means of organisms already present but whether or not the organisms in sewage will digest garbage remains to be shown. There is some hope that a suitable ratio between the dosage of garbage and sewage, or garbage and fresh sludge, can be found that will make possible the design of garbage-sludge digestion tanks, for sewage treatment plants, that will operate successfully.

Other promising features of the process are the possibilities of the production, at a low cost, of sludge richer in fertilizing value, or of greater volume of gas, or grease, or other by-products which may convert an otherwise unpromising process into a practicable method of garbage and sludge disposal.

FACTORS INVOLVED

In any problem of research the investigator first recognizes and summarizes the factors which will affect his problem. These factors should be examined to determine which are controllable in the investigation, and which are uncontrollable. All of the factors should be observed during the progress of the tests and, where possible, in any one test, all but two of the factors should be held constant. One of the non-constant factors should be subjected to a controlled variation and the effect on the other varying factor observed.

In the problem of garbage and sludge digestion the factors to be considered include:

- Ratio of garbage to sludge[1]
- Volume of garbage and sludge digesting[1]
- Method of making the mixture of garbage and sludge[1]
- Temperature of digestion[2]
- Characteristic or condition of digestion[1]
- Time of digestion[1]
- Characteristics of the garbage
  - Size of particles[1]
  - Age of the garbage[1]
  - Source of garbage (hotel, restaurant, residence)[1]
  - Predominating type of waste (meat, vegetable, fruit, etc.)
  - Organic matter, fixed and volatile
  - Nitrogen
  - Grease (ether soluble)
  - Acidity, alkalinity, or pH
  - Biochemical oxygen demand
  - Per cent of solid matter
  - Amount of cellulose
  - Gas production, both quantity and quality
- Characteristics of sludge
  - Source[1] (plain sed., digested, activated, etc.)
  - Solids; per cent volatile, fixed, dry.
  - Drainability
  - pH
  - Appearance, "streaking"
  - Biochemical oxygen demand
  - Ether soluble matter
  - Nitrogen content
- Characteristics of digested mixture of garbage and sludge
  - Solids; per cent volatile, fixed, dry
  - Odor
  - Color
  - Drainability
  - Appearance, "streaking"
  - Biochemical oxygen demand
  - Nitrogen
  - Fertilizing value
  - Grease (ether soluble matter)

[1] These factors are controllable. All others are uncontrollable.

[2] This factor may be controllable.

WORK AT THE UNIVERSITY OF ILLINOIS

Research work on this problem is being carried on at the sewage testing plant at the University of Illinois. Our equipment consists of a number of one-gallon bottles and 50-gallon casks in which various ratios of garbage and sludge are being digested, and of two identical Imhoff tanks, each capable of caring for approximately 80,000 gallons of sewage daily. One of these Imhoff tanks is dosed daily with garbage and the other is operated as a control, with domestic sewage only. A separate digestion tank of about 25,000 gallons capacity is also in use.

The plant was operated for three months during the spring of 1934, for the purpose of tuning it up, preparatory to the opening of a two-year run this fall. It is expected that different combinations of garbage and sludge will be made and the conditions or factors listed will be observed before any conclusions will be attempted. It is possible that some hydraulic experiments will supplement the biological and chemical control of the tests. Measures of the digestion of the mixture will include the following: volatile solids in the digesting mixture; gas production, both as to volume and quality; temperature of digestion; and physical characteristics of the mixture, such as drainability, color, odor.

PREVIOUS WORK

It is interesting to note that Keefer and Kratz at Baltimore (this JOURNAL, Jan., 1933 and March, 1934) and Fair of Harvard (*Ibid.*, March, 1934) have observed most, if not all, of the important factors involved. They have concluded that there is some hope for success in this method for the disposal of garbage. More intensive research, including the repetition of their tests, seems desirable to increase knowledge and to make more certain the truths of the presumptions made.

Plant Operation

SLUDGE DEWATERING—SAND FILTERS AND VACUUM FILTERS*

By Frank Woodbury Jones

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Trite, but true, is the statement that sludge is still the tough problem for the sewage plant operator. Odors come, and sometimes go, effluents join the brook and go on forever, but sludge remains, in one form or another, a constant reminder that the sewage of a community carries a tremendous quantity of bulk solid matter, which silently settles out and accumulates, often to the point of saturation and subsequent impairment of plant efficiency.

Notwithstanding the importance of proper sludge disposal, and in spite of all the schemes devised and practised for getting rid of this residue, it is to be regretted that operating data of most of our sewage treatment works contain less detailed information on this phase of sewage treatment than on any other. Although we make numerous determinations of moisture, pH, and volatile matter, a proper correlation of all the factors involved is woefully lacking and any attempt to draw conclusions demands liberal interpolation and interpretation of the data available. As illustration of the neglect to include sludge disposal data, an otherwise excellent sewage plant report of recent date dismisses this phase of the operation in a terse, short paragraph, thus:

"A total of 44 beds of sludge was drawn from the tanks during this year and a total of 15 beds of scum. All sludge drawn was well digested, dried out quickly and had no pronounced odor."

Again, we find frequently a lack of proper correlation of the data submitted. For example, simple arithmetic will show that 9,000 gallons of 87.5 per cent moisture sludge placed on 1,600 square feet of drying area will give a depth of more than 6 inches when first applied.

It may be seen, therefore, that the assembling and presentation of sludge data present difficulties beyond immediate control, and, in consequence, many conclusions must be based on judgment and experience.

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* Presented at the Eighth Annual Conference of The Pennsylvania Sewage Works Association, State College, Pa., June 28, 1934.

SOURCE AND QUANTITY OF SLUDGE SOLIDS

Any effort to provide for sludge disposal facilities should first include an estimate of the quantity of solids to be handled. In this connection the facts are often overlooked that the degree of treatment influences sludge production, and that the amount of sludge from partial treatment will not be as great as from complete treatment. Moreover, the type of treatment has marked effect on the weight and character of the solids deposited. The amount of moisture mixed with these solids determines the volume of sludge to be handled. Since doubling the per cent of solids halves the volume of sludge, the value of the efforts made to secure concentrated sludge is at once apparent.

The starting points in sludge solids estimates are: Accurate measurements of sewage flow, tributary population, and the determination of suspended solids of the raw sewage and of the effluents from the various steps in the treatment process. Without commenting upon the ramifications and irregularities of the suspended solids test, our own experience leads to the conclusion that, with proper attention to details of sampling and analytical technique, a true representation of sludge production can be obtained in the laboratory, provided frequent tests are made over a sufficient period of time.

The sludge of various kinds and the overflow liquors should also be carefully sampled and analyzed, and the quantities of total solids so obtained should be checked frequently against the sewage analyses; otherwise anomalous results are sure to appear.

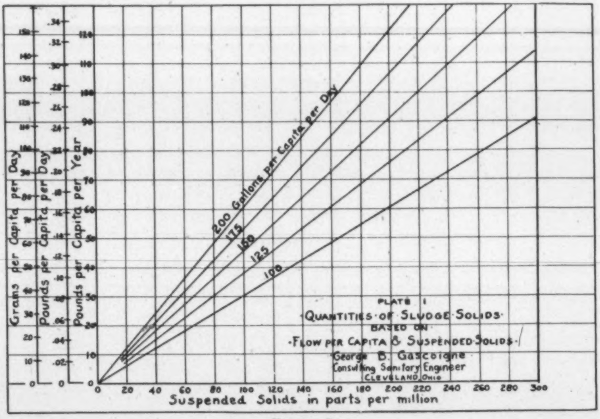

PLATE I

From the analytical and physical data, computations may be made of the quantities of bulk or sludge forming solids contained in raw sewage. Plate I has been prepared to show the quantities of sludge solids, based on suspended solids in parts per million, for various per capita flows. With basic data, including total sewage flow, tributary population, and total suspended solids, the quantities of dry sludge solids may be expressed in any form to suit the individual fancy.

A study of the curves in Plate I reveals graphically the wide fluctuations in the quantities of sludge producing solids in sewage of varying characteristics. The curves demonstrate, also, how misleading it is to use parts per million of suspended solids without the correlating values of total flow and tributary population.

Types of Sludge

Several types of sludge are produced in modern sewage treatment practice. For convenience, these may be classified as:

- Fresh Sludge
  - Plain settling tank
  - Short storage two-story tank
  - Chemical precipitation
  - Excess activated
  - Humus tank
  - Mixtures of any of the above
- Digested Sludge
  - Any single type of sludge or mixtures after digestion in two-story or separate digestion tanks, heated or unheated
- Mixed Fresh and Digested Sludge

Although advocates of some methods of sludge disposal reject the need for digestion, it is probably true that for most small and medium-sized sewage plant installations, during the next few years, digestion will be included irrespective of the method used for final sludge disposal. In order, therefore, not to attempt to cover too much ground, this present study will be confined to digested sludge.

Quantity of Digested Sludge Produced

Degree of treatment, character of sewage, and type of process are controlling factors in sludge production. Not all of the sludge-forming solids contained in raw sewage are removed by treatment, and not all of those so removed must be handled as sludge. Digestion of fresh solids reduces their total dry weight from 25 to 40 per cent or more, depending upon the character and organic content of the settled solids. Then too, it is often disregarded that a trickling filter does not unload all of the solids deposited therein. Analyses and plant records over a period of consecutive years show that the suspended solids applied to a filter may be reduced as much as 35 per cent within the filter. In the activated sludge process there is, also, possibly some loss by direct wet oxidation.

Applying the above reasoning, Tables I, II, and III have been prepared, not to show actual results, but rather as hypothetical values which illustrate typical plant performance. Digestion is estimated to reduce the dry solids by 35 per cent.

Tables Illustrating Quantities of Digested Sludge from Different Types of Treatment

I. Sedimentation and Digestion

Suspended Solids, P.P.M.		Sludge Solids, P.P.M.	
Raw Sewage	Settled Sewage	Fresh	Digested
100	60	40	26
125	70	55	36
150	75	75	49
175	82	93	60
200	90	110	71
225	93	132	86
250	100	150	98

II. Sedimentation, Trickling Filters and Final Settling Tanks—Digestion

Suspended Solids, P.P.M.				Sludge Solids, P.P.M.	
Raw Sewage	Settled Sewage	Filter Effluent	Final Effluent	Fresh	Digested
100	60	48	20	68	44
125	70	56	22	89	58
150	75	60	25	110	71
175	82	62	26	129	84
200	90	68	29	149	97
225	93	70	30	172	112
250	100	75	33	192	125

Values found in these tables applied to the curves on Plate I, give the unit quantities of dry sludge solids which must be handled under varying conditions of sewage characteristics and flow. Thus, a sedimentation plant with sewage containing 200 parts per million of suspended solids, and flows at the rate of 100 gallons per capita per day, will yield 21.6 pounds of dry digested sludge per capita per year, whereas the same sewage treated by the tank, trickling-filter process would produce 29.5 pounds, and by the activated-sludge process 36.5 pounds. If the suspended solids were 200 parts, and the flow 125 gallons per capita per day, the above values would increase to 27.0, 36.9 and 45.6 pounds per capita per year, respectively. These weights in all cases are those of dry solids. The volume to be handled will vary tremendously, depending upon the moisture content of the wet sludge.

III. Sedimentation and Activated Sludge—Digestion

Suspended Solids, P.P.M.		Sludge Solids, P.P.M.	
Raw Sewage	Final Effluent	Fresh	Digested
100	8	92	60
125	10	115	75
150	12	138	90
175	14	161	105
200	16	184	120
225	18	207	134
250	20	230	150

METHODS OF SLUDGE DISPOSAL

It is not within the scope of this discussion to describe or comment upon the various and sundry ways proposed and utilized for the drying and disposal of sewage sludge. These methods vary all the way from the broadcasting of fresh solids over the landscape, to the spraying of wet sludge into an oven. The method used by far most widely, in present practice, is the drying on prepared filter beds, either open or glass-covered. Recent studies point to attractive possibilities with vacuum filtration. Our present study, therefore, will be narrowed to considerations of these two methods without prejudice or favor, in accordance with the limited information available.

Sand Filters

Much has been written about the design and construction of sludge-drying beds. A thin layer of gravel underlying 12 inches, more or less, of fairly coarse sand of low uniformity coefficient, and overlying a bottom sloping to underdrains imbedded in gravel, will serve effectively. Other filter media may also be used. The condition of the sludge, however, more than the design of the filter bed, or the type of media, determines the drying period.

Sludge-drying beds are not as a rule utilized to their effective capacity. Some operators will not remove sludge until it is almost bone dry, others remove it in a semi-wet condition. Often there is a delay of several days after sludge is sufficiently dry for removal. In a test run made in 1929 at Marion, Ohio, it was found that there were 14 days in the year when the beds used were idle, enough in total to permit another flooding. Because of this general situation, supposedly inadequate areas would give greater yields if a definite program of filling and cleaning were strictly followed.

Sludge-drying beds may be open, or covered with glass as in greenhouse construction. For a given sludge it is generally conceded that the glass-covered bed, which was originated about 20 years ago at the Cleveland Testing Station, will permit in a year at least twice, and in some cases three times, as many floodings as will the open bed. Recognizing the exceptions which prove the rule, our experience confirms this general conclusion.

Accomplishments of Sand Beds

In the days of plain settling and early chemical precipitation, the dewatering of sludge on sand filters was well nigh impossible. It would not dry, and foul odors permeated the neighborhood. With the advent of the Imhoff tank and digested sludge, a new era dawned. The black granular product with slight tarry odor from this new settling device was reported to dewater on sand beds in a remarkably short time. Quoting from ancient history we read:

"The digestion of the sludge also reduces its sticky tenacious nature and facilitates its parting with the water.

"In normal weather sludge from a matured Emscher tank will dry on sand beds in from 3 to 5 days to a consistency fit to remove, while sludge from a septic tank requires at least two weeks' time and sludge from plain sedimentation tanks will require about 8 weeks in summer and at least twice that length of time in winter, to be dry and firm enough to handle.

"The rapid drying of sludge digested in Emscher tanks allows of very much smaller sand beds than for other kinds of sludge, in fact it is usual to provide only 1 square foot of bed for each three persons tributary to the tank."

The conclusions from sludge drying experiments at the Cleveland Testing Station in 1913 were summarized as follows:

"It will probably be possible to operate beds of this type (open sand beds) so that one square foot of surface will dry 0.4 of a cubic yard of sludge per year. The above statement applies when the original sludge has a moisture content of approximately 87 per cent and the removed product 70 per cent. (About 90 pounds dry solids per square foot per year.)

"Eliminating the three winter months of operation it is possible to operate beds of this type (glass covered sand beds) so that one square foot of surface will dry eight-tenths of a cubic yard of sludge per year. It is assumed that the original sludge and dried product have the same moisture contents as stated in connection with open beds." (About 180 pounds dry solids per square foot per year.)

In 1929, Mr. Floyd G. Browne and the writer conducted experiments on two glass-covered sludge beds and obtained results which led to the following conclusions:

"With a sludge averaging 7 to 7.5 per cent solids, it is possible with applications of from 8 to 10 inches depth to secure 20 dryings in a calendar year for a total disposal of 0.58 cubic yard wet sludge per square foot of drying area (about 75 pounds per square foot per year).

"An increase in the solids content of 1 per cent and a slight increase in depth of application not to exceed 12 inches will not greatly affect the drying period under favorable conditions. The quality of the sludge and the condition of the bed have an important bearing in this respect."

Turning now to the records of plant operation, we find wide variations in individual performance. The sewage plant operator has still to find a certain means whereby digestion can be so controlled as to produce a fairly dense and uniformly drainable and dryable sludge. The solids content of digested sludge varies all the way from 4 per cent upward, and it is not always the thin sludge which dewaters the best. The following table was published a few years ago, " to show the length of time required to dry sludges of different solids contents when applied at depths of 8, 9 and 10 inches to sand beds under favorable conditions."

Per Cent Solids in Sludge	8 Inches	9 Inches	10 Inches
4	5½ days	6 days	6 days
5	6½ days	8½ days	10 days
6	9 days	12 days	13 days
7	12 days	14 days	16 days
8	14 days	18 days	23 days

We do not question that these figures may be applicable to some sludges but they can by no means be regarded as of general application.

Data from several treatment plants are summarized in Table IV.

A study of these data is disappointing and misleading without knowledge of the conditions at each plant. It is apparent, however, that the density of the sludge has an important bearing on the unit quantity of solids each square foot will accommodate. Furthermore, as stated previously, the condition of the wet sludge is an important factor. Over-digested as well as under-digested sludge will slow up the drying process. It behooves the operator, therefore, who is plagued with sludge which dries slowly, to experiment with his treatment in an effort to improve the quality of the sludge. It is fitting to mention here in passing that a few years ago alum added to sludge applied to drying beds was advocated as an effective filter aid. Ferric chloride is now proposed. Both, we believe, have possibilities if artificial aid is needed.

Drying Bed Area Required

Where sludge beds are included in a sewage plant, modern design practice is to make them glass-covered, unless cheap material and sufficient area are available to justify open beds. Our observation, based on plant performance, leads to the conclusion that in a well operated treatment plant a glass-covered sludge bed can accommodate a total of 75 pounds of dry, digested solids per square foot per year, if worked to capacity. On this basis and referring to Tables I, II and II and Plate I, plants treating sewage with suspended solids of 175 parts per million and a flow of 100 gallons per capita per day, would require glass-covered areas as follows:

1. 0.24 sq. ft. per capita (sedimentation)
2. 0.33 sq. ft. per capita (trickling filters)
3. 0.43 sq. ft. per capita (activated sludge)

On the other hand, if a concentrated sewage with high flow rate is to be treated as typified by 200 parts per million of suspended solids and a rate of 200 gallons per capita per day, the sludge-drying area needed would increase to:

1. 0.57 sq. ft. per capita
2. 0.78 sq. ft. per capita
3. 0.97 sq. ft. per capita

The extent to which a drying bed would have to be operated with various densities and depths of sludges is shown on Plate II. These curves indicate that 75 pounds per square foot per year can be obtained with glass-covered beds when sludge with 8 per cent solids is applied 10 inches deep about 16 times per year. This should be possible.

TABLE IV.—*Operating Data, Sludge Dewatering on Sand Beds*

Place	Type of Plant	Sludge Filter Area Sq. Ft.	No. of Fillings Per Year	Depth in Inches	Per Cent Solids Wet Sludge	Per Cent Volatile Solids	Per Cent Moisture in Cake as Removed	Total Cu. Yds. Wet Sludge	Cu. Yds. Wet Sludge Per Sq. Ft. Per Year	Total Pounds Dry Solids Per Year	Pounds Dry Solids Per Sq. Ft. Per Year	Source of Data
Cleveland, Ohio, Southerly	Imhoff Tank—Trickling Filter Secondary Tanks	32,000 (covered)	13–14	9–10	8.4	55.0	70.1	13,738	0.43	1,996,400	62	1933 Report
Fitchburg, Mass.	" "	18,315 (open)	6.57	10.7	12.64	40.5	53.8	3978	0.218	845,380	46	6 Best Years Aver. 1916–1918–1921 1923–1924–1925
Fitchburg, Mass.	" "	18,315 (open)	3 to 8	—	13.15	—	52.1	3011	0.164	653,960	35	Average 1915–1930
Marion, Ohio	" "	2510 (covered)	20	9.32	7.15	53.4	67.7	1450	0.58	179,360	71	1929 Special Tests 2 Beds
Alliance, Ohio	" "	12,150 (covered)	10	10–12	6.0	58.4	58.7	4970	0.41	515,900	43	1930 Poor Sludge
Schenectady, N. Y.	Imhoff Tank—Trickling Filter (No humus sludge)	3040 (open)	10	7–12 (10.1)	5.25	—	65 ±	947	0.31	85,682	28	Typical Bed 1932
Flint, Mich.	Imhoff Tank—Trickling Filter Secondary Tanks	120,000 (open)	4.7	10.2	5.6	53.2	56.9	17,815	0.148	1,725,000	14	1933 Report
Elyria, Ohio	Imhoff Tank Activated Sludge Separate Digestors	12,000 (covered)	7.5	10.7	7.25	46.55	54.2	2944	0.245	368,125	30	1933 Report
Springfield, Ill.	Primary Settling Activated Sludge Separate Digestors	30,000 (10 open, 2 covered)	9.3	10	4.13–11.74 8.51	41.1	54.1	8030	0.27	1,475,350	49	1932 Report
Rochester, N. Y.	Imhoff Tanks	77,440 (open)	6 to 10	About 10″	8.2	46.4	—	20,603	0.266	2,924,800	38	Average 1924–1930

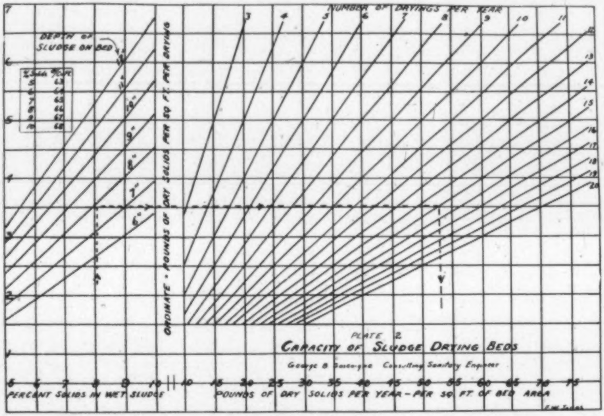

Plate II

Vacuum Filters

Sewage sludge can be dewatered on vacuum filters. Experience at Milwaukee and various other places has demonstrated the applicability of this method for activated sludge. Installations at Winston-Salem, N. C., Dearborn, Mich., Hagerstown, Md., and Chicago, Ill., have handled, for the most part, fresh sludge from chemical treatment or mixtures of fresh solids and activated sludge. To the best of our knowledge, vacuum filtration of digested sludge has been limited to experimental and demonstration units at Chicago, Ill., Baltimore, Md., Columbus and Cleveland, Ohio.

Much has been written during the past few years describing vacuum filtration and it is not necessary at this time to repeat what is found in current literature. Our comments will be confined largely to published data, which comprise only a small part of the total, and to our observations at Cleveland. No consideration has been given to the disposal of cake, other than dumping.

ACCOMPLISHMENTS OF VACUUM FILTERS

As with sand filters, the type and character of the applied sludge, and its pre-filtration treatment with chemicals, control the output of vacuum filters. It is now standard practice to prepare or condition sludge by the aid of chemicals, so that when applied to the filter it will part with its water most rapidly. The kind and amount of conditioner to add is the real problem for the plant operator, as this is perhaps the largest single item in operating costs. The conditioner most commonly and acceptably used is ferric chloride. Lime and ferric chloride also have been used successfully and other chemicals, alone or in combination, have given some promise.

Experience at Milwaukee, Charlotte, High Point and Hagerstown, indicate that when filtering activated sludge, the average output is 2 pounds or less of dry solids, per square foot of filter area per hour of operation. The cake as it leaves the filter contains approximately 80 per cent moisture.

The filtration of digested sludge is still in the experimental and demonstration stages. At Columbus, Imhoff tank sludge was filtered using ferric chloride alone, and in combination with lime, as a conditioner. The filter was 3 feet in diameter by 2 feet long, having 18 square feet of effective filtering surface. Cake produced averaged around 70 per cent moisture, and "it may be said that from 4 to 5 lbs. dry solids per square foot filter area per hour was a rate not difficult to maintain."

The work at Baltimore was most thorough and has been published in detail in This Journal. Two types of vacuum filter were used, one having 16 square feet of filter area and the other 18 square feet. "When dewatering the same sludge with all other conditions alike it is believed that the capacities of the two filters should be about the same."

The work at Baltimore demonstrated that sludges are not constant in their response to conditioner, and also that yields vary within rather wide ranges. In one group of experiments with ferric chloride added in amounts of from 3.79 to 8.11 pounds of anhydrous material per 100 pounds of dry solids to be filtered, it was found that the quantity of sludge dewatered increased as a greater quantity of ferric chloride was used until an average maximum output of about 11.5 pounds of dry solids per square foot of filter area per hour were dewatered when using about 6.8 pounds of anhydrous ferric chloride per 100 pounds of dry solids. The average moisture in the cake was 74.8 per cent and the pH value varied from 6.1 to 6.7.

In another group of experiments, "the quantity of ferric chloride used was varied from 5.60 to 17.11 pounds per 100 pounds of dry solids in the sludge, with an output of from 5.3 to 27.4 pounds of dry cake per square foot of filter area per hour." This sludge would not filter properly when using less than 7.0 per cent ferric chloride. From these experiences it was concluded that: "In order to determine the filtrability of digested sludge under all conditions a continuous series of tests lasting at least one year should be made."

At Baltimore, three estimates of cost were made, the first on the basis that one type of digested sludge could be filtered using 5¼ pounds of ferric chloride per 100 pounds of dry solids, to yield 7.6 pounds of dry solids per square foot of filter area per hour. A reduction of 10 per cent was included, as in the other estimates, to allow for a factor of safety.

It was estimated, also, that another type of sludge using 8.0 pounds of ferric chloride per 100 pounds of dry solids, would yield 14.0 pounds of dry solids per square foot of filter area per hour, whereas chlorinated copperas in the amount of 11.0 pounds per 100 pounds of dry solids was expected to produce 8.8 pounds of dry solids per square foot of filter area per hour.

At Cleveland, Ohio, an Oliver filter 5 feet 4 inches in diameter by 10 feet long, having a filtering surface of 165 square feet, was placed in operation in 1933 and about 100 runs of from one hour to three hours duration were made between April and November. Imhoff tank sludge was used for some 20 runs, whereas separate-digestion tank sludge was used in the others.

At first it was quite difficult to adjust the dosage of ferric chloride, due to frequent partial stoppages in the sludge pumps. The average results, and particularly those in the later tests when the mechanical difficulties were straightened out, are regarded as representative of what can be done with the Cleveland sludge under the conditions at that time.

From April to July, 21 runs on Imhoff tank sludge may be summarized as follows:

	Minimum	Maximum	Average
Gallons filtered per run	900	5,860	2,877
Length of run in minutes	50	184	102
Per cent moisture in sludge	95.1	90.4	93.5
Per cent volatile matter in sludge	54.5	59.9	54.9
Alkalinity, parts per million			1,900
Per cent ferric chloride added (dry solids basis)	4.9	16.4	8.5
pH of filter feed	4.9	6.0	5.3
Per cent moisture in filter cake	67.3	75.4	71.8
Yield, pounds dry solids per square foot per hour	3.1	7.9	5.7

In July and August, 19 runs were made on sludge from separate digestion tanks, which were supplied with settled solids from the Imhoff tanks. A summary of the results obtained shows:

	Minimum	Maximum	Average
Gallons filtered per run	1,805	3,910	2,892
Length of run in minutes	70	180	124
Per cent moisture in sludge	94.7	88.2	90.1
Per cent volatile matter in sludge	41.3	47.6	45.4
Alkalinity, parts per million			2,450
Per cent ferric chloride added (dry solids basis)	4.54	17.1	8.7
pH of filter feed	5.1	6.3	5.8
Per cent moisture in filter cake	65.9	70.5	68.0
Yield, pounds dry solids per square foot per hour	5.4	10.7	7.5

Runs made on separate digested sludge in September and October are summarized as follows:

	Minimum	Maximum	Average
Gallons filtered per run	1,784	3,947	3,256
Length of run in minutes	85	185	150
Per cent of moisture in sludge	87.3	93.2	90.8
Per cent volatile matter in sludge	45.9	52.0	49.0
Alkalinity, parts per million	2,090	3,790	3,070
Per cent ferric chloride added (dry solids basis)	4.6	10.0	7.7
pH of filter feed	5.9	6.8	6.4
Per cent moisture in filter cake	68.3	72.6	70.3
Yield, pounds dry solids per square foot per hour	4.2	9.1	6.2

A similar summary of 15 runs on separate digested sludge made in November shows:

	Minimum	Maximum	Average
Gallons filtered per run	1,840	3,086	2,791
Length of run in minutes	115	185	152
Per cent of moisture in sludge	90.2	93.3	91.2
Per cent volatile matter in sludge	49.4	55.0	51.7
Alkalinity, parts per million	2,210	4,200	3,610
Per cent ferric chloride added (dry solids basis)	5.6	10.1	8.1
pH of filter feed	6.3	6.9	6.5
Per cent moisture in filter cake	70.4	73.5	72.1
Yield, pounds dry solids per square foot per hour	4.4	5.9	5.0

A study of these summaries shows there was a progressive falling off in the yield although the differences in the average amounts of ferric chloride added were relatively small. The decreased output was attributed in part to the condition of the filter cloth and in part to the condition of the sludge.

A study of the work done so far at Cleveland does not reveal any outstanding correlation between characteristics of sludge, per cent of conditioner and output. However, certain tendencies were apparent which justified tentative conclusions, summarized as follows:

(1) Digested sludge can be conditioned with ferric chloride and be filtered.

(2) The yield of filter cake is greater, the greater the per cent of solids in the sludge.

(3) The percentage of volatile matter in the digested sludge, between 45 and 53 per cent, apparently has very little bearing on the yield of filter cake, except for a very slight tendency toward greater yield the lower the volatile matter.

(4) The percentage of volatile matter in the digested sludge, between 45 and 53 per cent, has no direct bearing on the quantity of ferric chloride used for conditioning.

(5) The per cent of ferric chloride used increases the yield up to a certain point after which increased ferric chloride produces no greater yield but apparently a falling off. The optimum percentage of ferric chloride for greatest yield in the digested sludges used was around 8.

(6) The effect of alkalinity and pH of the initial sludge on the amount of ferric chloride required is still to be determined.

Observations made during the operation which apparently are supported by the results point to the following conclusions:

(1) A dense sludge, that is one with moisture as low as 88 to 90 per cent, can be filtered without dilution, other than that necessitated by the ferric chloride solution.

(2) The best results on separate digested sludge are obtained when the pH of the filter feed is between 6.3 and 6.5. This may or may not be true for Imhoff tank sludge.

(3) With separate digested sludge, at least, it was found necessary that the moisture in the cake be under 75 per cent, otherwise, it would not leave the filter cloth without smearing.

(4) The filtrate is clear and contains some iron in the ferrous state. It is inoffensive as regards odor.

(5) Filter cake from digested sludge can be stored without causing offense, at least in piles which are relatively small.

(6) With continued use the filter cloth becomes clogged, and efficiencies both as to yield and dryness of cake fall off. As the clogging

of the cloth progresses, it is necessary to reduce the filter speed in order to produce a removable cake.

(7) Apparently, the behavior of the sludge as regards filtering changes with the seasons.

Area Required

It must be borne in mind that vacuum filtration of digested sludge is still in the demonstration stage. With full recognition of the fact that digested sludge can be filtered effectively, it must nevertheless be remembered that large scale plant operations will present problems not encountered in experimental work. Who, for example, in the early days of separate digestion, realized what a problem the proper disposal of supernatant liquor would become? It is to be expected, therefore, that in common with past experience, some of the results obtained to date will be tempered by full time, actual plant performance. For this reason, for separate digested sludge such as we have in Cleveland at the Westerly Plant, our present conclusion is that at least 8.0 per cent of ferric chloride will be required to produce an output of between 4 and 5 pounds per square foot of filtering area per hour on a year round basis.

Laboratory experiments made to study the effect of elutriation indicated some promise of savings by its use. Demonstration work on the filter, however, has not been sufficient to determine the applicability of this process to the Cleveland problem.

Cost of Sludge Dewatering

Any attempt to present cost figures for dewatering of sewage sludge whether by sand filters or by vacuum filters is beset with difficulties. Actual expenditures for the operation and maintenance of sand filters on individual plants are available, but any effort to turn these figures into unit costs on a dry solids basis is likely to lead to erroneous results. In general, however, it may be stated that open sand sludge beds with appurtenances have been constructed at costs anywhere from $0.30 to more than $1.00 per square foot. Greenhouse coverings are additional and vary from $0.85 to $1.70 per square foot of filter area. A liberal estimate for glass-covered sludge beds, complete with appurtenances, would range between $2.00 and $2.75 per square foot of filter area, depending upon the location and size of the installation.

The operating cost for removal of sludge cake including final disposal to a dump, is usually between $0.40 and $0.60 per cubic yard. From information obtained regarding the upkeep of greenhouses, it is learned that painting and glazing, inside and out, every three years should not exceed $0.03 per square foot per year. Other costs, such as sand renewal, estimated at two inches per year, insurance on glass-overs, and upkeep of equipment, would be well covered by an allowance of $0.04 per square foot per year. These figures based on installations approximating 14,000 square feet would be increased somewhat for smaller units and decreased for larger.

On the above basis, the total annual cost, with 20-year life of the structures, would range between $8.00 and $9.00 per ton of dry solids. Operation and maintenance costs, not including interest and depreciation, would vary between $4.00 and $5.00 per ton of dry solids.

In estimating the cost of vacuum filtration, provision must be made for a building to house filters and accessories, such as pumps, piping, mixing equipment, compressors, chemical storage, and the like. It must also be borne in mind that in setting up a vacuum filtration plant, certain spare units must be provided to guard against shutdowns and to assure continuous service. This differential is the better absorbed the larger the installation. It is questionable, therefore, whether vacuum filtration can compete on an installation cost basis in small projects.

Estimates made recently to filter about 10 tons of dry solids per day, including elutriation, showed a total cost, including land, of $388,000. Exclusive of elutriation and other appurtenances not directly essential to the filter installation, and to the facilities for the disposal of cake, the construction cost reduces to $250,000. Operation and maintenance costs, exclusive of interest and depreciation, are estimated at $19,000 annually, or approximately $5.20 per ton of dry solids. The total annual costs are computed at $12.50 per ton of dry solids.

Operation and maintenance costs of vacuum filtration will be greater than for sand bed drying in small and medium sized plants. This has been shown by the late E. G. McConnell at Charlotte, N. C., and also may be deducted from preliminary figures given by Mr. Donaldson for Hagerstown. In large plants, the costs will more nearly parallel. Until such time, however, when more definite and representative data than now obtainable are available, comparative cost figures should be viewed with open mind.

Requisites for Proper Sludge Disposal

For effective sludge disposal it is essential that the method used be practicable, economical, and inoffensive. If any one of these requisites can be emphasized more than another, it is that of inoffensiveness. The day has passed when stinking sludge areas will be tolerated. It is also necessary that any means adopted be workable and operative within reasonable cost. The fact that digestion not only substantially reduces the weight of dry solids to be handled, but also renders these solids inoffensive, is a strong reason for regarding digestion as a desirable unit in sewage plant design.

SUMMARY AND CONCLUSIONS

Examination of sewage plant operation records reveals a lack of reliable comprehensive and coordinating data on sludge disposal. This phase of sewage treatment should be given more attention.

The quantity of sludge solids to be handled and the areas required are dependent upon the characteristics of the sewage, the type and degree of treatment, and the rate of flow. The amount of water mixed with the solids determines the volume. All these factors should be taken into account when making designs and estimates.

At existing installations, digested sludge is most generally dewatered on open or glass-covered sand filters which, however, are not suitable for fresh sludges. Glass-covered filters are regarded as being two to three times as effective as open beds.

Drying of sludge is greatly dependent upon its physical condition. Where sand filters are operated to their effective capacity, which is rarely the case, facts support the conclusion that each square foot of glass-covered filter area can accommodate 75 pounds of properly digested dry solids per year.

Vacuum filtration has been used successfully on plant scale to dewater fresh sludge from chemical treatment and activated sludge plants after conditioning with chemicals. Its use for digested sludge so far has been limited to demonstration units.

Comparative and representative cost figures are difficult to obtain, yet, from the limited data available, it appears that for small installations the sand filter is still the more economical, both for construction and operation. The differential fades as the size of the project increases. In certain cases, expediency and adaptability may be the deciding factors for one method or the other irrespective of other considerations.

Vacuum filtration and sand filtration are alternative methods open to the designing engineer for dewatering digested sludge. Both will operate acceptably, size and location of the installation, method for final disposal, and cost, being the chief determining factors.

Much needs to be done before the actual, tried and proved performance of vacuum filtration on full plant scale is established, yet this method has its place. The old sand bed, however, is not yet ready to be relegated to the scrap heap, and with a strong competitor in the field, more attention will be given its performance. Any effort made to improve the dewatering and disposal of sludge in a practical, economical, and inoffensive manner, is a forward step and as such should command our attention and serious consideration.

DISCUSSION

Wellington Donaldson, with Fuller and McClintock, New York City: The position of the vacuum filter in the sewage treatment field is well established for dewatering activated sludge. In this field it has had no serious competition with sand filters, although the filter yields with activated sludge have seldom been much better than 1 lb./sq. ft./hr. of dry sewage solids.

For dewatering sludge from chemical precipitation processes the usefulness of the vacuum filter has also been well demonstrated, as in the operations of Winston-Salem and Dearborn.

Somewhat more recent have been adaptations of the vacuum filter in sewage treatment practice for dewatering both undigested solids and digested solids. In the case of undigested sludge, the vacuum filter is aimed to supplant the combination of digesters and sand drying beds. The writer has recently given results from this kind of operation at Hagerstown, Md., where mixed undigested sludges, conditioned with ferric chloride and lime, are filtered with an average yield of 2 lbs./sq. ft./hr. The same filters and method of conditioning give, with fresh solids only, (activated sludge omitted) a yield of 3 to 4 lbs./sq. ft./hr.

The use of vacuum filters to dewater digested sludge has until recently not been attractive as an alternate to sand-bed drying for the reasons that digested sludge had no potential nuisance value and filtration was more expensive and difficult than filtration of undigested solids. The picture has shifted materially as means have been found to condition the digested sludge and secure materially better yields than before were thought possible. In particular, the Baltimore experiments, during the last year and a half by Keefer and Genter, have indicated the possibility of securing practical yields of the order of 20 lbs./sq. ft./hr. With filter installations reduced correspondingly in size and cost, vacuum filters offer a definite threat to supplant sand drying beds, both open and covered.

Dr. W. Rudolfs, New Brunswick, N. J.: I would like to ask Mr. Jones one or two questions. He stated that enclosed beds have from two to three times the drying capacity of open beds. Is this conclusion based on parallel tests made in Ohio, or in Cleveland, or is that speculation?

Mr. Jones: Based on general observation of all the results obtained generally—not speculation. The information I have is based on the work we are now doing where we are using a digested sludge from Imhoff tanks which contains also final settling tank sludge and where the filter beds are now operating at pretty near capacity. Last year we got fourteen dryings during the year and the superintendent tells me that this year he expects to get more,—that is with a dense sludge and with dried sludge taken off at between 60 and 70 per cent moisture. I know that with ordinary beds if you got 7 dryings during the year, you were doing mighty well.

Dr. Rudolfs: Another question. You used about 8 lb. ferric chloride per 100 lb. dry solids in your experiments? Is that ferric chloride as sold? In other words 42 per cent ferric chloride or is it approximately 20 pounds of commercial material?

Mr. Jones: It is figured on the basis of 100 per cent $FeCl_3$. A gallon of the ferric chloride solution weighs about twelve pounds.

Dr. Rudolfs: There is a good deal of confusion in this respect. Some people think that you have to buy eight pounds of the commercial material whereas as a matter of fact that is not so. The commercial material contains only 42 per cent of ferric chloride.

Mr. Jones: It is bought on a dry solids basis.

Member: Mr. Jones stated that sludge cake can be stored in piles without creating a nuisance. I am wondering if you could do the same thing when the sludge is not so well digested.

Mr. Jones: No. I am talking about digested sludge. This discussion was confined to digested sludge.

Member: Mr. Jones stated that seasonal changes affect the filtration.

Mr. Jones: I said, apparently.

Member: Have you any reason to suspect that either poorer or better filtration results in the summer?

Mr. Jones: I am not in a position to make a definite statement regarding that.

Mr. A. L. Genter, Baltimore: I think I can answer that last question. Investigations made over two years ago by Keefer and Cromwell at Baltimore disclosed the fact that digested sludge required considerably more ferric chloride in summer than in winter, even though this sludge was from a heated digestion tank kept at constant temperature. One of my earlier studies on that particular problem was observing raw sludge undergoing digestion in winter and summer. We found that the amino-ammonia nitrogen of the raw sludge entering digestion tanks in summer was from 3 to 4 or 5 times what it was in winter.

Mr. John F. Laboon, J. N. Chester Engineers, Pittsburgh: Some of the older engineers, I believe, will agree with me in regard to open sludge beds. Comparisons are apt to be misleading because the results of the comparisons are dependent entirely on the assumed fact that sludge beds are all operating efficiently, which is not true. Therefore, the comparative efficiencies of open and covered beds should play a very important part in the compilations or comparative compilations of Mr. Jones.

Now with regard to open beds, I believe that in the past too many of the covered beds have been designed wholly for protection against the weather and, therefore, their utmost capacity has not been realized. With that in mind several years ago, in designing a covered sludge bed for the Torrance, Pa., State Hospital, in-swinging ventilating sash was incorporated with the idea that perhaps better ventilation of the bed might be obtained and, therefore, the moisture-laden air would be taken away from the sludge more rapidly. We believe defective ventilation in covered beds has resulted in poor operation and efficiency.

At Fostoria, Ohio, where we installed both open and closed beds in a parallel case, after two years of operation there was very little difference in their relative efficiencies. Fostoria is the only place I know of having both open and covered beds. It was found at Fostoria, too, that the operators prefer the open beds to the closed ones. For instance, they experience a clinging odor in the closed beds, and regardless of how much mechanical equipment is put in to handle the sludge, the operation and maintenance of the closed beds is higher than that of open beds. Taken all in all we have, after a number of installations of closed beds, come to the conclusion that the closed beds cannot be justified in efficiency and cost over the installation of the open beds.

With respect to the filtering of digested sludge which Mr. Jones brought out, I agree with him from my personal observations. I visited Charlotte and found there that the filtered raw sludge was most difficult to dispose of. It can't be permitted to accumulate. Furthermore, at a more recent installation which I visited, the plant was filtering raw and activated sludge. I found there was a difference of opinion between the superintendent of operation at that particular plant and the consulting engineer, because they have had difficulties with the disposal of filtered, raw and activated sludge. As a result, the superintendent has concluded that sludge digestion must come sooner or later at this plant in order to get away from the difficulties that are now experienced from odors resulting from the disposal of this material around the neighboring farms. They find, even after heavy treatment with chemicals, that the material must be spread very thinly over farm land in order not to defeat the purpose.

Mr. Wertz: Incineration will take care of that.

Mr. Laboon: Yes, I agree with you,—on large installations. However, with smaller communities where they have valleys and lagoons in which to dispose of the sludge, of course, the problem isn't so serious. Incineration is probably the answer to the disposal of sludge in large quantities.

Mr. Cleland: How do you get around weather conditions?

Mr. Laboon: I found that sludge in winter time, in a covered bed, did not dry very quickly. It was as long as thirty days before it could be removed. Some people—some operators—remove the sludge even if it is 80 or 90 per cent moisture just to get rid of it—to get it off the beds. Others will wait until it is bone dry. Since this is a function of time, and time is an element of efficiency, some standardization must be had of such factors before efficiency can be measured and determined.

F. B. Altemus, Norristown, Pa.: As a result of observations at the Norristown plant, where we have both the open and covered types, we find that with sludge, of say 91 per cent solids content as applied to the beds, with the covered type beds, we get no odors; on the open beds, if we have any rain, we do get a trace of odor. Also, as to the removal, that we are able to remove it more readily on the covered beds than on the open beds due to the better seepage, more uniform drying, and less sand removal with the removal of sludge. With the open beds, in attempting to get the same amount of dryness, we lose considerable time. I feel that at Norristown, regardless of the cost of installation, we are heartily in favor of the closed beds.

Mr. Jones: I think there is some misunderstanding about the function of the glass-covered sludge bed. I do not know that anyone ever claimed sludge would dry more quickly on a glass-covered bed than on an open bed under favorable conditions of wind and weather. But I have actually operated a sewage plant with open beds, for several years, and have experienced what it is to say, "We will clean the sludge beds tomorrow so that we can relieve our Imhoff tanks," when lo and behold! tomorrow it would rain and the sludge would have to go through another three or four days sunshine before the tanks could be relieved. On the other hand, if one has a covered bed, and the sludge is ready, one can remove it during a rain storm if he desires. On some plants, a rainy-day job is to remove sludge from one bed and pile it onto another to dry out until it can be ground and used for fertilizer. The rain will not affect this sludge, since it is protected, and protection from weather is the chief advantage of the covered sludge bed. It is a fact, also, that in such weather as we had last winter, there were five months when one couldn't use an open bed. Such limitations often present a serious problem of what to do with over-crowded tanks. If the sludge on a drying bed is not covered with snow and ice, it is possible to remove it in a frozen condition.

It is obvious that the amount of moisture in the sludge, as removed, determines to a great extent the effectiveness of the drying area. I know of one operator who, because he has plenty of drying capacity, doesn't remove the sludge until it is almost bone dry. Naturally, the efficiency based on number of dryings is low. On the other hand, experience shows that some sludges can be easily and readily removed from a sand filter when they have 75 per cent moisture, whereas others can be removed only at 65 per cent moisture, or even lower.

Mr. Tatlock at Dayton has changed from the use of six-tined, to fifteen-tined forks, and has found that he can speed up his sludge removal appreciably.

There are various factors that influence the sludge drying situation, and if we could be sure of bright, sunshiny weather all the time and all the year, it would make a deal of difference. In the old testing station days, it was concluded that sludge dried better in the open during good weather than under glass, probably because of inadequate ventilation, but nevertheless, the advantage of the covered bed was recognized.

The point is, that we want to get something that can be utilized on a year round basis, and a covered sludge bed can be and is so used.

PLANT OPERATION *

By W. L. Stevenson

Chief Engineer, Pennsylvania State Department of Health

The members of this association actually engaged in the operation of sewage treatment works need not be told why there should be good plant operation. Therefore, this presentation is mainly for the purpose of stimulating a discussion on what may be deemed moot questions.

The subject will be presented from four points of view, to wit, (1) to prevent harmful stream pollution, (2) to attain economy of public funds, (3) to provide assurance against sustainable complaints and damage suits, and (4) to have records to know efficiency and to obtain improvements.

Stream Pollution

The waters of the state belong to the Commonwealth, therefore pollution of a stream caused by the discharge of untreated or inadequately treated sewage is a matter of public concern over and above damage caused to lower riparian users. Obviously, therefore, the primary purpose in a municipality making a capital expenditure of its public moneys for the construction of a sewage treatment works, is to abate an existing nuisance or to prevent the arising of harmful stream pollution.

No matter how well the plant be designed and constructed, the fact remains that the initial capital investment will be of no avail, nor will the plant fulfill its intended purpose, if the works are not continuously well operated so as to produce the required quality of effluent. In fact, experience has shown that a skillful operator can obtain as good, and in some cases actually better, results from a slightly inadequate or obsolete treatment works than would be produced by the unskillful or careless operation of a good, modern plant. I have observed many such cases. Much depends upon the zeal, skill and integrity of the operator. Our Pennsylvania operators comprise a splendid body of men who are often required to operate more or less inadequate plants with meagre compensation, yet who produce good results in spite of the handicaps.

Economy of Plant

Municipal councils, being the representatives of the citizens, are naturally prone to be more liberal in appropriations from current income for activities from which the people of the community obtain a direct benefit, such as waterworks, light plants, parks, highways, etc., than for matters in which the public are not interested. Sewage treatment works generally are located down stream from the built-up part of the town site and, hence, the operation of the plant is not a matter of interest or concern to the town-folk, although perhaps of vital importance to downstream waterworks, as court decisions on responsibility for wastes disposal clearly prove.

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* Presented at the Eighth Annual Conference of the Pennsylvania Sewage Works Association, State College, Pennsylvania, June 29, 1934.

Even in what we now look back upon as days of municipal prosperity, it was not easy to obtain the appropriation for the operation of the sewage treatment works which the city engineer and the works operator knew was needed. And, of course, today with lessened municipal expenditures because of decreased income, the problem is even more difficult.

Notwithstanding this hard and inescapable fact, adequate appropriations for works operation and maintenance are in the interest of economy of municipal funds because an efficiently operated works will continue to serve the intended purpose up to, and even, at times, beyond the raw sewage load for which the plant was originally designed and constructed. On the other hand, inadequate operation will make necessary at an earlier date further capital investment for improvements, enlargements and betterments to the plant, and this, in turn, means increased outlay for interest on the new debt and payments to the sinking fund to amortize it.

In cases of municipalities whose comprehensive sewerage plan includes more than one sewage treatment works and where the first has been built and the municipality in the future will be confronted with the condemnation of parts of tracts of lands for the sites of other treatment works, substantial savings in payments for land condemnation may be had through the favorable impression made upon viewers or jurors by conditions at the existing plant of the municipality, if they are satisfactory. This includes neat appearance and freedom from offensive odors, both of which can be had only through adequate appropriation for plant maintenance and by good operation.

Complaints and Damages

The popular conception of a sewage treatment works is that it is a place of offense and nuisance and, therefore, no matter how well a plant be designed and constructed and how efficiently it be operated, in the beginning, the plant starts off with a handicap of a decided prejudice on the part of citizens dwelling in its neighborhood and of persons living down-stream from the point of discharge of the effluent.

Diligent effort to produce a good quality of effluent and to keep the plant free from offensive odors and unsightly appearance, definitely tends to minimize sustainable complaints or damage suits. Much may be done in this respect with but a limited appropriation, through thoughtful planning.

Records

The keeping of proper records of the details of operation of a plant will show increasing or decreasing efficiency in the various units. Study of the records which show increasing efficiency is a guide to the operator in maintaining or adopting the best and most efficient mode of operation. On the other hand, where the records show a trend toward decreasing efficiency in any of the units of the plant the operator is forewarned to correct conditions and forestall the development of trouble.

Furthermore, where a plant is well operated and records thereof kept with care, the municipality is provided with a strong defense in the case of complaints or damage suits.

Part of the records naturally include the results of analytical tests and these should be selected to suit both the kind of works and the various purposes for which analytical tests are made.

Discussion

H. M. Beaumont, Asst. Engineer, Bureau of Engineering, City of Philadelphia: As stated by Mr. Stevenson, the importance of skillful sewage plant operation cannot be too greatly emphasized. Satisfactory operation is dependent upon good design and construction, and upon the availability of sufficient funds for efficient operation, proper maintenance and competent management.

The number of the personnel and their training should be governed by the size and type of the treatment works. In order to attract and secure properly qualified men to serve as plant operators, their compensation should be commensurate with their responsibilities. For the aid of the sewage works operator, there have been established in the educational institutions of several states, short term schools where instruction is given in the general principles of sewage treatment and the management of sewage works. Membership in engineering societies and sewage works associations also affords opportunity for acquiring knowledge relative to the operation of sewage treatment plants.

It is unthinkable that a steamship company would place in the hands of an untrained man the operation of one of its great ocean liners, yet there are instances where public authorities have placed untrained men in responsible charge of the operation of sewage treatment plants involving large capital investments and holding great potentialities of danger to the health and welfare of the citizens and loss of public funds due to faulty or improper operation.

It is, therefore, essential that the operator should know the details of the plant layout, the function of each unit employed, and the quality of the plant effluent necessary to meet certain prescribed requirements dictated by conditions obtaining, or likely to obtain, in the receiving body of water.

It is obvious that no material should be received into the sewer systems which might tend to form deposits therein, injure the sewer structure and treatment works, or mechanical devices, or adversely affect the treatment processes employed.

A survey should be made of all industries located along the lines of the contributing sewers and where wastes are found which are known to be of such quality and quantity as to injure the structures or impair the satisfactory operation of the treatment works, the offender should be denied further drainage until the character of the waste is so modified as to place no undue burden upon the structures or treatment processes.

Such a survey might also aid the operator in locating so-called accidental discharges of unsuitable material into the sewer system and enable him to take such measures as will minimize their re-occurrence.

Mr. Stevenson has rightfully pointed out the importance of cleanliness and neatness throughout the entire plant. A reasonable expenditure of labor and material for parking the grounds and maintaining them in such a way that they may be pleasing to the eye, will without doubt prove to be a wise investment.

About 1916, following the adoption of the comprehensive sewage plan for the entire city of Philadelphia, proceedings were begun for the acquisition of real estate for the proposed treatment works. Owners of surrounding properties immediately set up claims against the city for anticipated losses due to the proximity of the sewage works to their lands. The claimants were able to produce many competent witnesses who testified to actual sustainable losses to property which had occurred in other cities of the country by reason of the operation of sewage treatment plants. The city made no attempt to dispute this evidence, which no doubt was true and reliable, but in lieu thereof called to the attention of the Board of Viewers the existing Pennypack Sewage Treatment Works, operated by the city since 1912 for the protection of the city water supply originating in the Delaware River. Upon the request of the city, the Board dispatched representatives to examine and report upon conditions obtaining at these works. These representatives reported the absence of odors or nuisance of any kind, the pleasing appearance of the grounds and structures, that residents of the vicinity made the plant the objective of a Sunday afternoon stroll, and that these works should be regarded as an enhancement to the value of surrounding property rather than a depreciation. The few hundred dollars expended at this plant for shrubbery, and the parking of the grounds, the care of the operator in maintaining cleanliness, and an orderly and pleasing appearance, resulted in the saving of many thousands of dollars to the taxpayers which would have had to be paid had the claims for anticipated property damage been sustained.

The nearer the sewage plant is located to human habitations, the greater should be the concern of the operator as to odors. It has been the observation of the writer that conscientious and painstaking sewage works operators are frequently less aware of odors than occasional visitors. Perhaps it might be well at times to call in disinterested parties to point out odors which might pass unnoticed, but which could, and should be corrected.

Some years ago a sewage pumping station, located in close proximity to high grade residences, was the cause of much concern to the writer because of odors. The station was maintained scrupulously clean, but some residents complained of odors from the incinerator employed for the burning of screenings. This difficulty was satisfactorily overcome by washing the screenings with tap water for the removal of urea prior to incineration.

There are some prejudices against sewage works which are difficult to overcome. A resident living near a sewage grit chamber for seven years, who thought the plant to be a water pumping station, admitted to the writer that he had not noticed any odors from this station until he discovered that it was a sewage works.

Records of detailed operation of sewage plants are as essential to the operator as are records to the manager of a large department store. Neither can hope to handle his job satisfactorily without complete and accurate records of each day's performances.

Records are not only to be kept, but they should be used. If faithfully kept and used, they may be of great value to the operator in his management of the plant and may postpone the day when extensions will be required to handle greater volumes of sewage.

Daily inspections should be made of each unit of the plant by the operator and he should record any unusual occurrences and see to it that all faulty conditions are immediately remedied. All mechanical equipment should likewise be inspected and maintained in good running order.

As time goes on, operating records become more voluminous and likewise more valuable. However, much of their value to the operator will be lost, due to this great volume, unless steps are taken to keep the basic information before the operator at all times. At the beginning of operation of the Pennypack Creek Sewage Treatment Works in 1912, Mr. Stevenson, at that time engineer in charge of the work, prepared a form 3½ ft. long by 2½ ft. wide, covering the calendar year, on which was recorded complete weekly data on plant operation. Such a record shows a rather complete story of the plant operation as to past and present performances and furnishes the operator, on one sheet, the data abstracted from hundreds of daily record sheets.

On another sheet of approximately the same dimensions, there were plotted in black and white diagrams for the calendar year the daily records of the more essential data. Such a record may be very helpful to the operator and should give him at a glance a clear picture of the plant operation.

In addition to their value for guiding operation, records of a well operated plant may provide a strong defense in the case of complaints or damage suits.

In the early days of operation of the Pennypack Plant, a number of cases of typhoid fever were reported in a section of the city deriving its water supply from the Delaware River. State health officials began their investigation at the sewage plant because of its proximity to the water purification works intake. The records of the Pennypack Plant indicated that since the beginning of its operation, the plant effluent had been low in suspended solids content, well oxygenated, practically sterile and free from B. coli, and not a probable source of river contamination. The operating records, therefore, had the dual value of sustaining the integrity of those responsible for the proper operation of the sewage works, and in not delaying the health officials in looking elsewhere for the trouble, which was found to be in cross-connections in the water supply system.

To enable the operator to know the workings of the plant units, certain tests are prescribed for the sewage and sludge. Samples should be collected and tested with the utmost care and fidelity, otherwise the determinations obscure the true conditions obtaining at the plant, and in consequence thereof the operator employs for his guide a measuring rod, the graduations of which are inaccurate.

The operator should be encouraged to make as many tests as time and his ability will permit. This should stimulate his interest in the work by showing him the importance of careful sampling, giving him a greater knowledge of the behavior of the plant units, and may suggest to him betterments in plant operation.

C. F. Grace, Polk: I have been the operator of a small plant for the last 24 years and, of course, the plant built in 1909 is an antique at this time. However, when I go around over the country and see plants more up-to-date, built in recent years, they seem to have fully as many troubles, if not more, than I have. My troubles have been small. I never had anything serious happen at any time. I have difficulties the same as everbody else has, seasonal changes, and things get into the sewers that shouldn't, but there is always a way to straighten out these things. The thing to do is to figure out what the matter is, or to call in some one who knows. I have always found that cooperation with the Department of Health representatives pays big dividends. I know the boys in the Department and probably six or eight of them, at some time or other, have been in my district. I find them to be a mighty fine bunch and always ready to cooperate and to give good advice.

Occasionally it is a good idea to put yourself on the carpet and see if you are doing everything you should. Take yourself to task, and you will find you can make a few improvements. There are a lot of things about an old plant that worry you more than on a new plant but at the same time everybody can't have new plants. A plant built last year is out of date now, so we will have to make the best of what we have to work with, and if you make an honest endeavor to do the best work with the facilities you have, I think that is all that the State Department of Health requires.

F. W. Jones, Cleveland, Ohio: I was very much interested in what my friend Beaumont said about people who didn't know it was a sewage treatment plant. Several years ago we had quite a bit of trouble regarding reputed odors from our Southerly Plant. Mrs. Jones and I used to go around two or three times a week so we could make an honest check. One day we took some folks with us who had never seen the plant. We didn't tell them where we were going. We drove down through the gates and asked what they thought of this place. They said, "This is nice—looks very nice." "Do you know what this place is?", I asked. "No," was the answer. "This is one of our sewage plants," I replied. "Why, it smells around here," was the response.

Plant records are very important. It is quite necessary that we have pH and B.O.D. and some of the other things, but it is also necessary that we have other records concerning the physical characteristics. I have one place in mind where it is a popular pastime for the people to bring suit regarding odors. This city built a new plant some six or seven years ago and it was a foregone conclusion that this same group of people would bring suits—that was their business. So as part of the routine operation we prepared blanks which the plant operator could use in making observations every day, at different places around the works, as to odor and wind conditions and have those filed away. Unknown to the operator, a second blank was prepared and handed over to the Director of Public Service and the Mayor of that town with directions that they should employ some disinterested person, unknown to the operator, who would go out in that vicinity and make certain observations regarding odors—whatever he found he put down. That wasn't done long—it was done for a short time, and then they got a young fellow to operate the plant and he didn't see the necessity of it. The city is now faced with suits amounting to $102,000.

I have been through Mr. Grace's plant and immediately one goes there, one is convinced and impressed with the fact that somebody lives around the place. If we had more sewage operators of the type of Mr. Grace and others I might mention, we wouldn't have so much kick about the bad appearance and bad reputation of sewage plants.

I have another in mind. It is, incidentally, the same plant against which I said damage suits are being brought. Some years ago I went there and there was a rocking chair in the pumping station and it was a pretty well used rocking chair. I told the operator that was no place for a rocking chair but he didn't take the hint. I took the matter up with the officials and the next time I went there the rocking chair had disappeared. But administrations come and go, and I happened to be there not so long ago—the rocking chair has been replaced and the plant is in pretty bad shape.

ACTIVATED SLUDGE SEWAGE TREATMENT WORKS, HARLEM VALLEY STATE HOSPITAL, WINGDALE, NEW YORK *

By Henry Ryon

Senior Sanitary Engineer, Division of Engineering, N. Y. State Dept. of Public Works

Location and History

The Harlem Valley State Hospital, one of the 19 hospitals for the insane owned and maintained by the State of New York, is located at Wingdale, on the Harlem Division of the New York Central Railroad, about 70 miles north of New York City. The land was originally acquired by the State Prison Commission as the site for Wingdale Prison. Its development was started in 1917 and included, in addition to several buildings, a water supply system, a sewerage system and a sewage treatment works. This sewage treatment works consisted of a screen chamber, an Imhoff tank, a dosing tank, intermittent sand filters and a chlorinating plant, and was designed for a population of 600 persons. The prison was never completed but the water and sewerage systems and the sewage treatment works, with the exception of some of the sand in the sand filters, were installed.

A few years later, in 1924, the property was transferred to the State Department of Mental Hygiene for a hospital for insane patients. The new hospital occupied the prison buildings that had been completed and several buildings that were added. The original sewage treatment works soon became inadequate, and in 1927 the State Department of Public Works was asked to prepare plans for a sewage treatment works for the hospital to serve a population of 1500 persons. It was found impractical to utilize much of the original installation, and a new plant was designed consisting of a screen chamber, an Imhoff tank, a dosing chamber, intermittent sand filters and a chlorinating plant. The plant was completed in 1928 and operated satisfactorily until its abandonment in 1933 when the new plant was started. The cost of the works was $79,184.20. This figure may seem high but it must be remembered that the flow of sewage of state institutions averages about 200 gallons per capita per day and that all the sand for the sand beds had to be transported from Long Island.

The works had been in operation about two years when the State Department of Mental Hygiene found it necessary to increase the population of the hospital from 1500 to 6000 persons, including inmates and employees, and the State Department of Public Works was requested to provide sewage treatment for that population. The natural way to accomplish this seemed at first to be to retain the existing type of treatment and to enlarge the works in proportion to the population. Difficulties were, however, encountered immediately. To serve an institution population of 6000 persons, sand filters having a net area of about 12 acres would be required and additional area would be required for the embankments between and around the beds and for the tanks. To obtain this area it would be necessary to extend the beds to the north to the property line, where the neighbors were none too anxious to have the institution sewage near them, to the west to a main highway, Route 22, where the motorists would probably complain of odors, and to the south and east to points very close to the new institution buildings, which would undoubtedly result in complaints from the inmates and attendants, as complaints had been received previously by the occupants of buildings farther away regarding the odors from the smaller existing works. The installation of trickling filters ahead of the sand filters, which would permit the use of a higher rate on the sand beds and consequently the use of smaller beds, was considered. The reduction in total area required was, however, found to be small, and the advantage gained would have been more than offset by the necessity of abandoning the existing tank and of placing the new settling tanks and the trickling filters considerably above the natural grade where they would be very conspicuous. Furthermore, a preliminary estimate of cost, based largely on the cost of the existing works, indicated that an entirely new works of a different type could probably be built at less cost than enlarging the existing works. It was therefore decided to abandon the existing sewage disposal works and to construct an entirely new plant in a more isolated location.

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* Presented at the Spring Meeting, New York State Sewage Works Association, Jamestown, June 15, 16, 1934.

Degree of Purification Required

The natural drainage of the institution grounds is toward Swamp River, which flows through the property in a northerly direction on the west side of the buildings, and is the only stream into which it is practical to discharge the sewage or sewage effluent from the institution. On leaving the hospital property, Swamp River flows in a northerly direction about 7 miles to Ten Mile River which flows easterly across the state line and discharges into the Housatonic River near Bulls Bridge in Connecticut. As its name implies, Swamp River is a sluggish stream with very little fall that meanders through swamps for almost its entire length. Wingdale, a village of about 100 inhabitants, is located on the river about a quarter of a mile below the sewer outlet, and there is a summer colony about three miles below the outlet at Dover Furnace where the residents bathe in the river. Water is taken from the stream for washing, swimming pools, ice ponds and similar purposes but no public water supply is taken from any of the streams below the institution.

The watershed area tributary to the river above the institution is about 19 square miles, and the natural dry-weather flow for a few days during most years is about 2 cu. ft. per second or 1,300,000 g.p.d. This flow will be materially reduced at times in the near future for a part of the water supply of the institution is to be taken from the stream above the sewage disposal works and the capacity of the pumping station is 1,440,000 g.p.d. The average sewage flow from the hospital with its proposed population of 6000 persons will probably be about 1,200,000 g.p.d. It was therefore necessary to provide a type of sewage treatment works that would produce an effluent that could be discharged into a sluggish stream with dilution, at times, of only one to one or less, without creating a nuisance and without rendering the water unfit for the uses mentioned above. Sand filters would undoubtedly satisfy these conditions, but the topography is such that they could not be installed except at a prohibitive cost, even though trickling filters were installed ahead of them and a high rate of filtration used. It was therefore decided to install a treatment plant of the activated sludge type.

General Type of Works

The elevations of the new buildings are so low that it is impossible to drain the sewage to any works by gravity, the basements of some of them being below the level of the river. The sewage from the old buildings might have been conducted to the works by gravity but long lines and inverted siphons would have been required, the cost of which did not appear to be warranted. This made it seem advisable to provide a pumping station to lift all the sewage.

The works were accordingly designed to consist of automatically cleaned bar screens, a pumping station, primary settling tanks, aerators, final settling tanks, sludge digestion tanks, glass covered sludge beds, a chlorinating plant and the necessary pumping and heating equipment. For convenience in operation, the pumping station was located in an L of the power house, with the screens in a room adjacent to it in the same L. The only suitable location for the other units of the treatment works was about 2/3 of a mile from the power house, and consisted of a narrow strip of land between a swamp on one side, where foundation work would have been difficult, and a rocky hill on the other, where the cost of excavation would have been excessive. It therefore became necessary to arrange the units of the works in a line on this narrow strip.

The capacity of the works had to be sufficient to handle and treat the sewage of 6000 persons. From experience at other institutions it was known that the average flow from this population is about 1,200,000 g.p.d. and the maximum flow for short periods as high as 4,500,000 g.p.d. These figures were used as the basis of the design.

Screens.—The screens, which precede the pumps, are in duplicate, slide gates being provided so that either or both screens may be used. Each screen is set in a concrete channel 3 ft. wide and 3 ft. deep. The screens are inclined at an angle of about 45° and consist of 3/8 in. by 3-in. bars 1 inch apart. An automatic screen cleaning mechanism is provided for each screen. These mechanisms are controlled by differential floats which start the screens when the difference in the sewage levels above and below the screens reaches a predetermined height. Alarm bells are provided in the pump room to warn the operator of any stoppage of the machines. The cleaning mechanisms discharge the screenings onto draining platforms from which they are picked up manually with forks and deposited in cans which are lifted to the ground level by an electric hoist. The screenings are buried.

Pumping Station.—From the screens the sewage flows into the suction well, a covered concrete basin 71 ft. long and 15 ft. wide extending the full length of the pumping station. The depth of the suction well below the inverts of the inlet pipes is about 7½ ft., but since the bottom slopes steeply toward the pump suctions, the maximum capacity is only about 40,000 gallons or the equivalent of approximately 30 minutes average flow.

The pumping equipment consists of 84 in.–450 gal. per min. horizontal centrifugal pumps, each directly connected on the same base to an electric motor. The pumps are set below the surface level in the pump well and each is connected to it by a separate 8 in. suction. Seven pumps will lift the estimated maximum peak flow of 4,500,000 g.p.d., leaving one pump in reserve. The pumps are automatically controlled by a switch having eight contactors operated by a single float. When the sewage rises to a point about 3 ft. above the suctions, the controller starts the first pump; when the sewage rises 6 in. higher the controller starts the second pump and for each additional 6 inch rise another pump is automatically started until the capacity of the pumps in operation is equal to the rate of flow in the sewer entering the suction well. As the rate of sewage flow decreases the pumps are automatically stopped in the reverse order. A selector switch is provided so that the sequence of operation of the pumps may be changed. A float gauge records continuously for sewage level in the suction well. An overhead crane is provided for use in repairing or removing the pumps and their motors.

The pumps discharge through a force main about 2100 ft. long and against a static head of approximately 21 feet. It will be noticed that as each additional pump starts, the water in the suction well is 6 inches higher, that is the total static head against which the pumps operate is 6 in. less. In designing the force main it was made 20 in. in size so that the additional friction loss in it as each pump started would be only about 6 in., thus keeping the total head and consequently the capacity of each pump approximately the same, regardless of the number of pumps operating.

Measuring Weir.—From the end of the force main the sewage flows through a gravity sewer about 1200 ft. long to the weir chamber at the entrance of the sewage treatment works. This concrete chamber contains a 4 ft. rectangular weir. A float gauge is installed in a small brick house adjacent to the weir chamber, and this gauge automatically records the head on the weir and also the flow of sewage in millions of gallons per day.

Primary Settling Tanks.—The sewage flows from the weir chamber to the inlet channel of the primary settling tanks. There are two of these tanks arranged so that either or both may be used. Each tank is 72 ft. long, 16 ft. wide and 7 ft., 6 in. deep, making the total capacity of the two tanks 130,000 gallons. With both tanks in use the detention period based on the average flow will therefore be 2.5 hours and at times of maximum flow about 0.6 of an hour. The sewage enters each tank through ten 6-in. submerged ports at the inlet end, is deflected by a wooden baffle, passes through the tank and leaves over a weir extending the full width of the outlet end. The concrete skimming trough forms a baffle at the outlet end.

Each tank is equipped with a mechanism for sludge removal, consisting of transverse flights carried by endless chains running over sprockets, which sweep the sludge to hoppers at the inlet end. The flights of this mechanism return at the water level and skim the tank, carrying the skimmings to the outlet end. They are 10 feet apart and move at a speed of 2 feet per minute. The mechanism for each tank is driven by a separate one h.p. motor. Horns are installed in the pump house to warn the operator of any stoppage of the mechanism. A skimming mechanism of similar design to the main sludge removing mechanism but only about 10 ft. long is provided at the outlet end of each tank. This mechanism is driven by the flights of the sludge removing mechanism and is just above the surface. It is provided with four metal flights fitted with rubber squeegees, which sweep the skimmings over a weir into the scum troughs. A flush valve admitting sewage from the tank is provided for washing the scum from this trough into the scum well.

Aeration Tanks.—The effluent from the primary tanks flows directly into the adjacent aeration tanks. These tanks consist of sixteen hopper bottomed units each 24 ft. square and 13 ft. deep, to the bottoms of the hoppers, making the capacity of one unit about 40,000 gallons and of the sixteen tanks 640,000 gallons. Each unit is equipped with an independent mechanical aerating unit supported on a concrete slab forming a walk across the unit. Each aerator consists of a wheel about 5 ft. in diameter, which revolves on a vertical shaft at about 60 revolutions per minute and throws the sewage in a spray over the surface. A draft tube about 3 ft. in diameter extends from the wheel to the bottom of the hopper of the unit causing the aerator to draw from the bottom and creating a circulation of the sewage in the unit. Each aerator is driven through reduction gears by a 2 h.p. electric motor.

The sixteen units are arranged in two parallel lines of eight each. A wall separates the two rows. The first two units of each row are also separated from each other and the other units by walls. Between the other units there are no walls above the hoppers. The inlet channels are so arranged with sluice gates that 6, 7, 8, 12, 14, or 16 units may be used at one time, thus making it possible to obtain aeration periods of 4.8, 5.6, 6.4, 9.6, 11.2, or 12.8 hours, based on the average flow of sewage, without allowance for return sludge. The arrangement of the gates also permits the use of the first unit or the first two units of each row for the reaeration of the return sludge.

The outlet gates from the aeration tanks discharge into a channel extending the full width of the last two units, from which the effluent flows over a weir 49 ft. long into a channel leading to the secondary settling tanks. The length of this weir was designed to keep the variation of the level in the tanks between maximum and minimum flows less than one inch. The weir is adjustable and can be moved vertically about 3 inches. The aerators are also individually adjustable so that they can be raised or lowered to give the best agitation.

Final Settling Tanks.—The final settling tanks, located at the outlet end of the aeration tanks, are two in number, each 74 ft. long, 16 ft. wide and 7 ft. 7 in. deep. The total capacity of the two tanks is therefore 133,000 gallons or the equivalent of about 2.6 hours average flow, not allowing for return sludge.

The influent enters through ports at the inlet end, the same as in the primary tanks, and leaves over weirs near the outlet end. These weirs extend along both sides of each tank for 44 ft. from the outlet end and on both sides of a transverse trough placed about 15 ft. from the outlet end. There are no weirs across the ends. The total length of outlet weir of each tank is 110 feet. The weirs are built in sections about 6 ft. long and are adjustable vertically so that they may be set to give the best results.

The tanks are equipped with sludge collecting mechanisms similar to those in the primary tanks, except that the flights return well below the surface and no provision is made for skimming. An independent 1 h.p. motor is provided for each mechanism. The flights move with a velocity of 1 ft. per min. and sweep the sludge into hoppers at the inlet end. Two 8-in. risers are provided in the hoppers in each tank through which the sludge rises to the sludge trough by gravity, the bottom of the trough being about 16 in. below the water surface of the tank. The upper ends of the risers are adjustable so that the quantity of sludge drawn from each may be varied.

Sludge Pump House.—The sludge pump house is a concrete and brick structure 42 ft. by 28 ft. in plan, with the pump floor 10 ft. below the ground level and a gallery around the entire interior at the ground level. This structure houses the sludge pumping equipment, heating equipment, transformers, electric controls, gas controls and line feed apparatus. A small laboratory table and cabinet is provided in one corner of the gallery for the use of the operator. An L on one side provides space for the chlorinators. There is no door between the chlorine room and the main room of the building.

The sludge pumping equipment includes two raw sludge pumps, two excess sludge pumps and three return sludge pumps.

Each raw sludge pump is a 10-in. single acting, single cylinder plunger pump connected by an enclosed reduction gear unit to a 5-h.p. motor mounted on the same base. The stroke of each pump can be set at 3, 4 or 5 inches and each motor has four speeds. It is thus possible with either pump to obtain twelve rates of pumping, varying from 13 to 63 gal. per minute. The suctions of these pumps connect by separate lines to the two sludge hoppers and the scum well of the primary settling tanks. The discharge is into the tops of the digestors.

The excess sludge pumps are the same as the raw sludge pumps, except that the motors are 3 h.p. The suctions of these pumps connect to the sludge trough of the final settling tanks and the discharge is into a manhole on a gravity sewer leading to the inlet of the primary settling tanks.

The three return sludge pumps are of the same type as the others, but each has two 10-in. cylinders. The motors are of 5 h.p. and have two speeds. With three adjustments of the stroke each pump therefore has six capacities. By using different speeds and strokes and different numbers of pumps, it is possible to obtain almost any desired capacity from 38 to 378 gal. per minute. Based on the average sewage flow of 1,200,000 gallons per day, these capacities allow the operator to vary the amount of return sludge from 4½ to 45 per cent. The regulation of the quantity of sludge returned is done entirely by the adjustment of the pumps. These pumps draw from the sludge trough of the final settling tanks and discharge into the inlet channel of the aeration tanks.

A dry-feed lime machine is located on the gallery and connected to the suction of the raw sludge pumps for applying lime to the raw sludge as it is pumped to the digestors. The machine has a capacity of from 7 to 125 pounds per hour.

The equipment for heating the digestors and also the pump house is located on the pump floor of the pump house and consists of a gas-heated and an oil-heated hot water boiler. The rated capacity of the former is 564 and of the latter 6,600 sq. ft. The size of the gas-heated boiler was determined from the estimated amount of gas that will be generated. The size of the oil-heated boiler was determined by estimating the amount of heat required to maintain the sludge in the digestors at 80° F. and the house at 60° F. during the winter. The gas-heated boiler will, from previous experience at other places, maintain the digestors at the proper temperature during the summer, but it will be necessary to use the oil-heated boiler also during the winter months. The boilers are cross-connected and automatically controlled by thermostats in the hot water line. The hot water is kept at 130° F. An excess gas burner is provided for disposing of any excess gas during warm weather. A circulating pump having a capacity of 50 gal. per min. is installed in the hot-water return to provide forced circulation of the hot water.

Digestion Tanks.—There are two sludge digestion tanks, each 35 ft. in diameter and 16 ft. deep. The capacity of both digestors is 30,000 cu. ft. or the equivalent of 5 cu. ft. per capita. The digestors are covered by an earth embankment. The supernatent liquid overflow connects about 2 ft., 6 in. below the top, making the actual capacity available for sludge storage approximately 24,000 cu. ft., or the equivalent of 4 cu. ft. per capita. Each digestor is equipped with a mechanical stirrer which revolves about a vertical shaft at a rate of 2.4 revolutions per hour. The mechanism is driven by a 2-h.p. motor through a worm gear. Bell alarms ring in the sludge pump house if the stirring mechanism becomes overloaded.

Four sampling cocks are provided on each digestor for sampling the sludge from different levels. The supernatant liquid flows by gravity to the inlet of the primary settling tank through the same sewer that carries the discharge from the excess sludge pump. There is a 3-foot gas dome on the top of each digestor and these domes are connected through a drip pot, gas meter and water seals to the gas-heated boiler and the excess gas burner. The sludge flows by gravity from the center of the bottom of each digestor to the sludge beds.

Sludge Beds.—There are two sludge beds, each 76 ft. by 38 ft. in plan, affording a total area of 5,600 sq. ft. or the equivalent of 0.93 sq. ft. per capita. A separate glass house covers each bed. The filtering material consists of 12 in. of sand and the beds are each divided into three sections for convenience in distributing the sludge. A carrier on an overhead trolley is provided for removing the dried sludge. The underdrains are connected to the outlet of the chlorine contact tank mentioned below.

Chlorination.—As stated above, the chlorine equipment is located in an L of the sludge pump house. The equipment consists of two solution feed chlorinators, each having capacities of from 20 to 200 pounds of chlorine a day. The chlorine solution lines are arranged so that the chlorine solution may be discharged either into the effluent line from the final settling tank, which passes under the chlorine room, or into the weir chamber at the inlet of the primary settling tanks, or into both. The chlorine solution line to the inlet of the primary settling tanks is about 400 ft. long and is of 4-in. acid proof tile encased in concrete. The pre-chlorination was provided primarily for odor control. The chlorinated effluent is discharged into a chlorine contact tank having a capacity of 9,000 gallons or about 10 minutes average flow. From the chlorine contact tank the chlorinated effluent flows through a 24-in. outlet sewer about 250 ft. long to Swamp River.

COST

The cost of the sewage disposal works, including the pumping station and force main, was $258,300.69. Without the pumping station and force main the cost was approximately $213,140.

RESULTS OF OPERATION

The works were put in operation under rather adverse conditions in the middle of December, 1933, and insufficient time has elapsed to give very reliable data on operation. The hospital buildings are being completed and occupied and the population of those tributary to the sewers has now reached about one-half that for which the works were designed. Only half of the units of the works, however, are in operation so that the load per unit is approximately that for which the works were designed. The results of routine tests made by the operator of the works in April, 1934, with a sewage flow of about 500,000 gal. per day were as follows:

Screenings	6.4 c.f.p.d.
Return sludge	98,000 g.p.d.
Raw sludge to digestor	2,000 g.p.d.
Excess sludge to primary tank	2,040 g.p.d.
Solids in aeration tanks (cylinder)	16.2%
Solids in return sludge (cylinder)	89.0%
Power consumed (entire works, clarifiers, aerators, sludge pumps, digestors but not sewage pumps)	357 Kw. H. per day
Power consumed (aerators)	248 Kw. H. per day

Settleable Solids	Raw	Primary	Final, Not Chlorinated	Digestion Tanks
Imhoff cone c.c. per l.	11.1	0.1	0.0	—
Turbidity p.p.m.	160	140	12	—
pH	7.1	7.2	7.1	6.8
D.O. p.p.m.	1.0	0.8	1.9	—
B.O.D. p.p.m.	175	105	10	—
Stability (days)	—	—	20	—
Temperature ° F.	54	52	44	68

B.O.D. Swamp River	1.9 p.p.m.
D.O. Swamp River	2.8 p.p.m.
Residual chlorine (outlet)	0.7 p.p.m.

The figures for B.O.D. and D.O. given are the averages of several catch samples and, while not as reliable as might be desired, will serve to give some idea of the results being obtained. The other figures are averages of daily tests for the month.

The temperature of the raw sewage was taken at the weir chamber. At the screens the average temperature was 60° F., showing a loss of about 6° F. in the force main.

The low pH and temperature in the digestion tanks is accounted for by the fact that the tanks were being filled for the first time and had not been brought to proper condition.

Discussion

W. B. Marshall, Chain Belt Company, Milwaukee, Wisconsin: In the portion of his paper covering the sludge pump house at Wingdale, Mr. Ryon has given a concise description of this part of the plant, but there are several features that seem worthy of more explanation.

The clean and orderly appearance of the sludge pump house is outstanding. Adequate working space has been provided around the pumps. The piping is in trenches covered with floor plates. Valves are next to pumps on both inlet and discharge lines. Long radius elbows have been used to reduce friction. Large air chambers make sludge flow steady, with quiet and efficient operation. Many of these features add materially to the attractive appearance of this pump house—but of course they are important primarily because they give better operating conditions.

From this standpoint, the flexibility in capacity variation of these pumps is also very important. As Mr. Ryon mentioned, the stroke of each pump can be set at 3, 4 or 5 inches. In addition, each of the two raw sludge pumps and the two excess sludge pumps have four-speed motors. Accordingly, for any stroke setting, four capacities are instantly available merely by turning the handle of the speed control, without the necessity of using any tools. The four capacities at any one of the stroke settings have a relationship of 1, 1½, 2 and 3; the low capacity thus being ⅓ of the high capacity. Being plunger type pumps with positive displacement, the desired capacities are secured regardless of head conditions, sludge density, etc.

The three double plunger pumps used for sludge return give an even better example of flexibility. The pumps can also be set for 3, 4 or 5 inch stroke and have two-speed motors. With the 3 pumps set at the 3 stroke positions, that is No. 1 pump 5 in. stroke, No. 2 pump 4 in stroke and No. 3 pump 3 in. stroke, it is possible to get from 38 to 302 gal. per minute by choosing the right pump or pumps and the right speed. This range of capacity corresponds to 90 degrees of the entire range and gives 4.5 to 36% return sludge capacity, based on average sewage flow of 1,200,000 gal. per day. In this range of capacities there are 21 different capacities available and a total of 24 possible combinations.

Other novel features of these sludge pumps are:

Shearing pin protection against sudden severe overload.

Horizontal flap valves to allow free passage of heavy sludge and large solids.

Inside packing. The packing is clamped between the two portions of the plunger instead of being in a stuffing box at the top of the cylinder.

Circulating cylinder lubrication. The packing lifts the oil, wiping it on the cylinder wall. The excess flows back into the inside of the plunger, through holes in the top of the plunger. This prevents oil on the outside of the cylinder.

Walking beam drive. This construction gives more direct plunger thrust and less sidewall pressure than overhead cranks or eccentrics.

Enclosed gear reduction unit. All gears precision cut and shafts mounted on Timken bearings, in oil tight housing mounted on pump base.

Slow speed of only 40 strokes per minute in contrast to 60 or more in usual installation.

The installation as a whole reflects credit upon the engineers, and is obviously the result of much careful planning and study. There is only one suggestion that might be offered for a similar future installation. Plunger pumps are self-priming and do not need to be submerged to get gravity flow to the pump suction. In fact they will operate more efficiently with a slight suction *lift* than with a suction *head*. If the sludge pump is to be used for tank dewatering as well as for normal sludge pumping, it is advisable to set it about 15 feet higher in elevation than the bottom of the sludge hoppers or sump. This will usually save considerable excavation in building the sludge pump house, and will improve, rather than impair, sludge pump operation.

E. M. Jones, Simplex Valve and Meter Co., Philadelphia, Pa.: Mr. Ryon's most complete paper leaves little for discussion. However, the reasons given as a deciding factor toward the selection of the activated sludge method of treatment are indeed interesting.

It has long been the opinion that the initial construction cost of activated sludge plants plus their higher operating costs, as compared with trickling filters, are so great as to over-balance not only the higher degree of purification obtained but also the elimination of odor nuisance as well.

The preliminary estimates of the Wingdale plant conclusively prove the error in this reasoning. Some idea of the comparative initial costs of plants similar to Wingdale may be interesting. For institutions, these vary from $9.00 to $33.00 per capita with the average cost being approximately $17.75 per capita.

Mr. Ryon has commented on the high degree of purification required and has mentioned that activated sludge treatment offers the only possible economical solution. With the type of plant installed at Wingdale, remarkably high reductions in B.O.D. and suspended solids can be obtained. Manufacturers' guarantees indicate that when recommendations covering the number of units and their detention periods are followed, reductions in B.O.D. will be better than 90%, with reductions in suspended solids better than 95 per cent.

The results at Wingdale indicate that these guarantees are being bettered.

Mr. Ryon has stated that simply by the opening or closing of sluice gates, aeration periods of 4.8 to 12.8 hours can be obtained. This not only offers the opportunity of varying the degree of purification easily, if desired, but also enables the operator to maintain power consumption of the aerator units at a minimum. Each of the aerator units at Wingdale has a daily capacity of 100,000 gallons of plus 25% sludge return, with a detention period at this rate of 7.72 hours. Thus from rates of from 600,000 g.p.d. to plant capacity, aerators can be cut in or out of service for practically each 100,000 gallon change in daily flow rate. A much greater degree of flexibility can be obtained, if required, by the addition of suitable channels and gates.

Although Mr. Ryon has stated that the plant has not been in operation a sufficient length of time to enable the compilation of complete data, the power consumption for treatment only is indeed excellent. Data from comparable sized plants of similar design have shown that the total cost of treatment should not exceed $30.00 per million gallons. This figure includes labor, maintenance and power costs.

Tests conducted on other plants of this size have shown that the average power consumption throughout the entire plant (but not including, of course, pumping to the plant) does not exceed 22 h.p. per million gallons with power required for aeration alone from 12.5 to 16 h.p. per million gallons. These low operating figures are worthy of consideration.

One other point which might be commented upon is the fact that in plants similar to Wingdale constant supervision is not required. Completely mechanized as it is, with automatic safeguards on all equipment, the plant should not require more than nominal supervision once it has been placed in service. At a plant of this size, one man, working 8 hours per day, should be sufficient. Since maintenance of all units can be expected to require nothing more than frequent inspection and necessary lubrication of moving parts, the remainder of the operator's time can be spent in the conducting of such routine tests as are required for intelligent operation and in performing the many small jobs which go hand in hand with sewage plant operation. This fact applies not only to institutional plants but to municipal plants as well.

OPERATING DIFFICULTIES AT THE FREDONIA SEWAGE DISPOSAL PLANT *

By Thomas Heubi

Superintendent of Water, Light and Sewers, Fredonia, New York

One primary operating difficulty has faced the Fredonia sewage disposal plant, and that is the problem of cannery wastes. Fortunately, we have now solved the most serious questions involved.

In the early years of our plant's existence cannery wastes gave no end of trouble. Our difficulty was unique, and probably faced by no other community in our section of the state. Canneries in the western fruit belt are mostly located in villages too small to support a sewage disposal system. Fredonia in 1927 installed a disposal plant intended to accommodate the domestic sewage from a village of 5500 persons. No industrial wastes were received, save from the fruit packers and grape pressers. From the latter, including now two wineries, and formerly grape juice factories (notably a branch plant of the Welch Company) only liquid refuse enters the sewage. But the canneries formerly dumped enormous amounts of solid waste into the village sewer system. You can appreciate the magnitude of our problem by the fact that at present one plant alone, under the screening arrangement now in effect, disposes of seventy tons of refuse each season. From each of five other institutions poured similar foul streams of putrescent vegetable matter. Seeds would sink in the Imhoff tank, but the decaying skins floated on top. The extra load on the plant was serious enough; the handling of floating solids proved excessively expensive, since such material had to be skimmed by hand. The job had to be done three and four times each day and occupied up to two hours on each occasion. Thus, three-fourths of a man's time was consumed each day for several months of the year. Further, the odor was obnoxious. Since the nearest residence is only a few hundred feet distant, we could not overlook the olfactory problem.

We endured the situation until 1931, when Charles Holmquist, Director of the Division of Sanitation of the State Department of Health, sent a representative here to make a survey. After investigating the problem, he interviewed the officials of the six factories concerned, and persuaded them to install mechanically cleaned and operated screens, 20 meshes to the inch. Thereafter, gross solids in cannery wastes no longer entered the sewers.

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* Presented at the Spring Meeting of the New York State Sewage Works Association, Jamestown, June 15–16, 1934.

Although relieved, our difficulty was not completely solved. The wind carried a most disagreeable odor from the filter bed during the summer and fall. Three years ago we attacked this situation by chlorinating the sewage in the dosing tank, by means of a portable chlorinator. Fifteen pounds of the chlorine introduced into the tank every day from early in July to the last of November has made the disposal plant less offensive to the sense of smell.

The acid cannery sewage caused foaming in the Imhoff tanks. This complaint remains with us. For neutralization purposes we chiefly rely upon forcing lime into the tanks by water pressure during the canning season. During the tomato pack, which lasts through August and September, we use 150 to 200 pounds of lime per day. Last year this normal addition sufficed to prevent foaming. Removal of sludge also helps.

An ever-present source of trouble of another kind lay, until recently, in our reception of surface water which caused a heavy load upon our system. We estimate the capacity of our disposal plant at 1,125,000 gallons per day. Upon eleven occasions during 1931 and 1932 the flow ran well above 2,000,000 gallons. About twice a month during 1931 the disposal plant received a flow greater than its theoretical capacity, and during 1932 the flow was above capacity one-fifth of the year. But the significant fact is that the periods of load were grouped together. The average flow for April, 1931, was 1,229,094 gallons per day, more than 100,000 above capacity. For the first week of that month, in fact, the average stood at 2,100,000 gallons. The month of August that year averaged 1,131,165 gallons per day. Most excessive of all we count the load of the first four months of 1932, with their combined average flow of 1,300,000 gallons each twenty-four hours. Surely, these are exceptional months. But so inelastic a piece of equipment as a disposal plant must be prepared for the peak load.

In common with similar grants of right to other communities, Fredonia's permission to operate a disposal plant forbids the discharge of storm water into the sanitary sewage system. Again, in common with most places, this rule has represented an ideal to be achieved rather than an accomplished fact. We have, however, taken large strides toward the accomplishment of this ideal. Our original sewage system included a number of receivers whose sole purpose was the discharge of rain water into the disposal system. During May the last four of these receivers were eliminated by the laying of two new surface water sewers. Other special drains for surface water now relieve the sewage system of roof water from all the business section and from houses along several streets. One of these conductors serves Fredonia Normal School, where collection of water on the huge roof caused considerable load on our facilities in the past. The extent of our accomplishment is indicated by the reduction in average flow at the plant from 850,000 gallons during 1931 and 1932 to 666,000 in 1933. Not since July of 1931 has an influent of 2,000,000 gallons been recorded in any single day, and 1933 saw only one flow above capacity.

Roof leaders of probably 95 per cent of Fredonia residences still empty rainwater into the sewer system. We hope to eliminate this practice in five years. In the meantime no danger exists. We estimate the flow from this source at not above 50,000 gallons per day.

That the surface water has not created a disastrous situation may be attributed to the generous scale upon which the plant was originally constructed. This disposal plant was designed to accommodate a population of 10,000. Fredonia's people now number scarcely more than half that total. At present, only about three-fourths of our families use the system but new sewers are being laid every year.

Our ample facilities account in part for our unusual freedom from severe operating difficulties. We have a trunk line thirty inches in diameter, as large as Jamestown's, where the normal flow of sewage is nearly five times that of Fredonia. We have a housed bar screen with one-inch openings. On either side of the Imhoff tanks are sludge beds each 90 ft. 9 in. by 55 ft. Our filter bed measures 220 ft. by 110 ft. and is covered with stone to a depth of six feet. There are 210 nozzles. In a brick house are two chlorinators, one of which is always kept in reserve for emergencies. The tile outfall line is of 16-inch diameter.

In one respect our original arrangement proved defective. The water main used to clean the underdrains in the sludge beds, only two inches in diameter, failed to give adequate pressure for thorough cleaning. Under a FERA project a four-inch pipe is now being laid, with two-inch lines running to each sludge bed. The force of this volume of water through the two-inch end pipes will provide much greater pressure.

A mechanically-cleaned bar screen would be most convenient, although we see no immediate prospect of such an improvement. At present, removal of screenings is done by hand labor and it is a laborious task. To prevent jamming, a man is often busy for ten or twelve hours keeping the bar screen clear during a rainstorm.

In most other respects, our system is very satisfactory. Chlorine dosage is at the rate of about 100 pounds per million gallons. Chlorine content of the effluent varies from 0.6 to 0.8 parts per million. The Imhoff cone test shows 5 to 10 c.c. per liter in the influent, and neither at the dosing tank nor in the final effluent is found any trace of solid matter. Even in bitter cold weather we have had no trouble due to low sewage temperature. During February, 1934, with an average air temperature of 19.3 deg. F., sewage temperature varied only a degree or two from 50 degrees.

Financing the disposal plant has never caused any problem. Our equipment cost originally $160,000. All expenditures, including running costs, upkeep and improvements, totalled about $3500 last year. We derive a little income from the sale of sludge for fertilizer at fifty cents a load. Farmers five to seven miles away have driven in to buy the sludge, which we can't produce fast enough for the demand. We realized $38.50 from this source in 1933.

In short, we feel that we are remarkably well situated. The worst of our surface water troubles are over, and we can see the time not too far distant when the sewage system need no longer be burdened with storm water. The cooperation of the State Department of Health has helped our cannery waste problem immeasurably.

Discussion

A. F. Allen, N. Y. State Department of Health, Buffalo, N. Y.: Mr. Heubi has discussed two problems which confronted his village; one of which is common in many communities, namely, the reception at the plant of excessive quantities of surface, roof and ground waters, and second, the reception at the plant of large amounts of industrial waste of fresh vegetable origin. Difficulties in the treatment of such wastes are experienced by many other communities and the method of attack on the problem used by Fredonia might well be copied by other communities faced with similar problems.

The elimination of excessive amounts of industrial and vegetable wastes was accomplished by cooperation between the industries and the village and was carried through to completion only after many years of endeavor to establish cooperative action. The industries now remove from their wastes the bulk of the solids in suspension. Generally, for this purpose, revolving fine screens have been installed. The treatment of the remaining solids in suspension and the solids in solution apparently does not seriously overtax the sewage disposal plant. Possibly this is an illustration of the fact that adequately designed and competently operated plants can carry, for short periods, a considerable overload without resulting in any marked deterioration in the character of the effluent discharged by the plant.

In this connection, it may be of some interest to recall the experience during recent months of three other sewage treatment plants called on to handle industrial wastes of an unusual nature. The plants are the Woodlawn sewage district in the town of Hamburg, the Blasdell village and the Lackawanna city plants. The first two are only a few hundred feet apart and the third is about a mile distant from the first two. All of them experienced difficulty in handling acid iron wastes during the months of April and May, 1934. The first appearance of these acid iron wastes occurred at about the same time at each of the plants. In addition, the Blasdell plant received large amounts of viscous oil and grease, although it is believed at this plant that the particular source of entry of the oils into the system is known, and recently the portal of entry has been closed. While it is not definitely clear that the iron entering the three systems may have had a common source of entry, it is quite safe to say that at each plant it is the result of increased industrial activity of the iron and steel industry in the Buffalo district. Within a few hundred feet of both the Woodlawn and the Blasdell plants a large iron and steel plant, which for several years previously had been operating at only a small fraction of its capacity, or had been completely closed, was operated at 100 per cent capacity during the period of entry of the acid iron waste into the plants. Practically the same situation existed at two large blast furnaces tributary to the Lackawanna plant.

The conditions at the Woodlawn plant received more careful study than at the other two plants and some facts regarding this plant may be of interest.

About April 17, 1934, the first effects were felt. The first effect was a slight loss of residual chlorine in the treated sewage. As we now know, this was probably due to the presence of acid and ferrous iron in the sewage, although in the absence of daily pH tests of the raw sewage, such explanation cannot be proven by analytical data. About the same time there was a slight increase in the settleable solids in the effluent of the Imhoff tank. Conditions rapidly became worse in the next few days, the residual chlorine being lost in the treated sewage on the 19th and even though the chlorine dosage was increased some five-fold, no positive test for residual chlorine could be obtained with the orthotolidin solution. Settleable solids in the tank effluent increased fifty-fold, although the bulk of the settleable solids was a reddish brown precipitate, undoubtedly iron hydroxide. This condition was maintained at or about the same degree of intensity for about a week. During the middle of this week residual chlorine tests were begun using starch iodide, and this reagent usually showed the presence of small amounts of residual, although, as you know, no definite amount of residual can be accurately determined with this reagent. Everything that the sewage came in contact with became coated with deposited iron hydroxide or iron oxide, and the plant presented a very unsightly appearance. This condition gradually improved. Conditions were nearly normal by May 5, and were considered quite normal by May 15, 1934. A few analytical data will indicate the intensity of the condition. On April 20, Imhoff cone tests of the raw sewage showed 1.5 c.c. of coarse sewage solids, on top of which 7.5 c.c. of red floculent material settled. The sample of raw sewage collected April 22 showed 320 p.p.m. of iron, of which 300 parts were in soluble form. The total solids were 1951 p.p.m., of which 1300 were mineral residue. The pH was 5.0. Another sample collected April 24 of the raw sewage showed a chlorine demand of about 6.0 p.p.m. The pH at the time was 4.1. The bacteriological examination of a sample of the settled trickling filter effluent prior to chlorination showed a 37 degree count of only 550, with gas formation in 1/10 c.c. portion, but not in 1/100 c.c. portion in the presumptive test for B. coli. This would seem to indicate that the acid, or the iron, or both were having some effect in reducing the bacterial flora of the raw sewage. Bacteriological examination of a sample collected May 14, when the physical evidence was that raw sewage conditions were nearly normal, showed a 37 degree count of 28,500 with confirmed B. coli in 1/10,000 c.c. in the trickling filter effluent. In the same sample, the total iron was 5.0 p.p.m., of which 0.75 p.p.m. was in solution. The pH had risen to 7.5.

As long as the sewage remained acid much of the iron remained in solution and passed on to the plant. However, in the latter stages of the period much of the iron remained in the plant, although some of it was being rapidly discharged from the filters. Just what ultimate effect this may have on the operation of the plant is not yet known. Sludge from the final settling tank is discharged back into the Imhoff tank, from which it is drawn to the drying bed.

Sludge was drawn from the Imhoff tank to the drying beds April 28, at about the time of the maximum iron concentration in the raw sewage, but before any of the sludge from the final settling tank had been discharged into the Imhoff tank. When this sludge had sufficiently dried for removal, a sample was collected for iron determination and it showed 4.35 per cent of iron on a dry solid basis. Since that time the final settling tank has been drawn off twice a week to the Imhoff tank and undoubtedly subsequent batches of sludge will show a much higher iron content.

Very similar experiences, although perhaps less marked, were noted at the Blasdell and Lackawanna plants, although the Blasdell condition was complicated by the presence of enormous amounts of grease on the flowing-through compartment of the Imhoff tank. Early this week the surface of the gas vents at the Blasdell plant presented a very unusual picture. The water level was some eight inches above the water level in the flowing-through compartment and was covered with a reddish liquid having a metallic sheen; undoubtedly the result of the combination of iron with the organic matter present. No sludge has been drawn at this plant since the beginning of the period of trouble although it will be drawn within a week, and the character of the sludge will be noted with interest.

The Lackawanna plant experienced difficulties with iron and acid wastes but they were much less marked than at Woodlawn, and due to the frequency of sludge removal both from the primary and secondary settling tanks, not much difficulty has been experienced, except that apparently at the present time the filters are unloading large amounts of solids and while conditions were satisfactory early this week, it is probable that at the present moment the secondary sludge drying beds are insufficient to handle the load from the final settling tank.

These instances illustrate the ability of domestic sewage treatment plants to handle unusual and apparently excessive amounts of industrial waste, as the ordinary operating tests have all indicated that the effluent of the plant in general complied with all the requirements for a satisfactory effluent, save possibly that period at the Woodlawn plant when residual chlorine was not observed, using the orthotolidin reagent. Whether or not the starch-iodide reagent would have showed a residual on these days will, of course, never be known, but undoubtedly the high acid content of the material rather effectively sterilized the sewage, and apparently the organic matter was satisfactorily removed by the plant.

I wish to comment on one other point of Mr. Heubi's paper, in which he notes the final completion of the storm sewer system necessary to eliminate completely such surface water from the sanitary sewer systems and his statement of the intent to continue the elimination of roof water from the sanitary system.

This village has taken advantage of every opportunity to avail itself of financial assistance from state and federal sources to effect the separation of storm and sanitary drainage. It is an endeavor which might well be copied by many other communities of the state.

Industrial Wastes

THE POPULATION EQUIVALENT OF CERTAIN INDUSTRIAL WASTES *

By C. K. Calvert and Elliott H. Parks

Supt. of the Indianapolis Sewage Disposal and Garbage Reduction Plants, and Industrial Wastes Chemist

The sewage of Indianapolis is strong whether measured in parts per million or on the basis of population served, which is estimated to be 90 per cent of the total. The sewage flow has varied from 163 gallons per capita per day in 1927 to 141 in 1933. The equivalent population, based on 0.17 lb. of 5-day B.O.D. per capita per day, has varied from 773,000 in 1929 to 587,000 in 1933, with a connected population of 341,100 or an indicated population of nearly 2.5 times the actual, prior to the reduction in industrial activity.

During the past winter an investigation of the major waste-producing industries was made as an F. E. R. A. project.

The volume of waste from an industrial plant was measured by a weir set (1) in a manhole on the private sewer, (2) within the plant if opportunity offered, (3) or in the main sewer above and below the plant sewer and the plant flow gotten by difference. The accuracy of weirs under such conditions is not high but every effort was made to provide as accurate measurements as possible. The gauges were read at intervals of 10 or 20 minutes throughout a period of observation. At the time the gauge was read, a sample was taken in an amount proportionate to the indicated flow. These samples were composited into samples representing flows of 1 to 6 hours, depending on the apparent frequency of major variations, with the compositing period held constant for any one plant. The samples were examined as promptly as possible, no samples being more than 15 hours old, during which time storage was at 3° C. without chemical preservative.

The volume of work in each plant was obtained from the man in charge of operation.

Laundry.—The laundry does a general business and is representative of the industry. It is estimated that the one under observation handles about 10 per cent of the total commercial laundry business of the city;

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* Presented before the Seventh Annual Convention of the Central States Sewage Works Association, Fond du Lac, Wisconsin, September 27, 1934.

its population equivalent was multiplied by ten to give the total industrial equivalent.

Creamery.—The creamery receives only cream, from which butter is churned. The residual buttermilk is evaporated. It is known that buttermilk is dumped into the sewer occasionally, in which case the losses are greatly increased. Practically all of the waste comes from can and equipment washing. It is estimated that this creamery churns about one-half of the butter produced in this type of plant. The equivalents obtained were doubled in arriving at the total population equivalent.

Dairy.—The dairy observed produces a general line of products. Milk not disposed of otherwise is evaporated, which accounts for the discrepancy between the raw milk received and the products listed. This dairy receives about one-third of the raw milk entering the city. The equivalents were multiplied by three in arriving at the total population equivalent.

Canning.—On the days observed, the canning plant packed only pork and beans. It is regrettable that information could not have been obtained when other products were being handled. The plant was not operated at full capacity and this, as well as the nature of the pack, resulted in a very low figure for the plant throughout a year.

Starch.—During part of the investigation, samples and measurements were taken within a starch plant to segregate the wastes from four principal operations. Obvious errors entered into the measurements and sampling of the small and very variable flows so that general figures only can be given.

	Percentages	
	Volume	B.O.D.
Condenser Water	46	12
Gluten Cone Overflow	27	50
Feed Press	20	30
Starch Press	7	8

Production of the main product results in small volume and strength of waste. Occasional laboratory experiments over a period of several years indicated that almost 50 per cent of the B.O.D. could be removed by efficient sedimentation. It is not proven that the material so removed would pay for the process but there is no doubt that it could be added to the feed. The load from the starch plant is an important part of the total to be treated at the sewage works.

Meat Packing Plants.—Four small packing plants are served by one sewer, with no domestic sewage, which allowed observations to be made on the waste from a relatively large kill, in small establishments, in comparison with that from a large plant. The total kill in the small and large houses is in the relationship of 1 to 6 while the population equivalents are less than 1 to 3. At first glance it would appear that operation on a larger scale results in the saving of more waste; from the appearance of the wastes it is obvious that more blood escapes to the sewer from the small plant. In all determinations made, the per animal waste was materially greater from the small plant, but it should be noted that about 32 per cent of the animals killed at the small plant were cattle and only 10 per cent were cattle in the large plant kill. The animals killed were computed to "hog equivalents" by assuming that the waste from slaughtering one head of cattle is 2.5 times as much as from one hog and that hog and sheep killing result in the same amount of refuse. Calculating the per animal waste on this basis still shows a greater waste from the small plants in every determination except oxygen consumed, the population equivalent based on B.O.D. being 50 per cent greater.

It is interesting to note that the data for large and small packing plants combined, without conversion to hog equivalents, check remarkably well with those reported by the U. S. P. H. S. (Bul. 171).

Paper Board.—The paper-board plant waste goes directly to the river and is not included in the total industrial load. On account of the known slow oxidation of cellulose, 10-day as well as 5-day B.O.D. determinations were made. The 10-day incubation gave a population equivalent per ton of production of 157, or almost 50 per cent more than was indicated by the standard 5-day incubation. This is of interest in the special case under consideration since the waste enters the stream in a pool where a considerable detention period and much sedimentation occur. Thus the effect of much more than the 5-day B.O.D. is concentrated in a rather small part of the stream.

Garbage Reduction.—The waste from the garbage reduction plant is not mixed with the sewage. The drainage of liquid from green garbage constitutes a part of the waste but is of minor importance. The heaviest part of the load comes from the water drained from the cooked garbage. During the summer, 200 tons of green garbage may be received at the plant. At this rate, the cooker water B.O.D. has an equivalent population value of 67,200 or 10.7 per cent of the total B.O.D. load received at the sewage works in 1933. The waste is disposed of at this time by digestion along with the sewage sludge in open deep digestion pits. Preliminary laboratory tests indicated that it would interfere little or none with the sludge digestion, though odor nuisance was anticipated. In actual practice no increase in odor has been noted and, so far, there has been no noticeable effect on digestion. The figures in the table do not include the condensed steam from drying tankage. This latter waste consists of volatile organic acids and a small amount of nitrogen compounds. On the basis of a 200-ton day, the per capita equivalent is

Indianapolis Industrial Waste—1934

Period of Observation		Type of Industry and Volume of Work Done	Unit Used	Gallons per Unit	Pounds per Unit							Total Population Equivalent
					Solids		Oxygen		Organic Nitrogen	Ether Soluble	Population Equivalent	
Days	Hrs. Day				Total Vol.	Susp.	Cons.	5 Day Demand				
1	8	Laundry—2800 lb. dirty clothing	100 lb.	1485	8.25	5.08	1.79	4.04		2.16	23.8	668*
1	24	Creamery—8000 lb. Butter Made	100 lb.	466	5.01		0.20	1.57	0.33	5.05	9.2	736*
1	10	Dairy—155,000 lb. Raw Milk Rec'd	100 lb.	132	1.83		0.38	1.29	0.08	0.16	7.6	11,782*
		Produced—										
		Fluid Milk . . . . 51,600 lb.										
		Cream 14,000										
		Butter 1,200										
		Cot. Cheese 910										
		But. Milk 3,870										
		Choc. Milk 1,290										
2	9	Canning—309,700 lb. Pork and Beans	1000 lb.	1220	17.35	2.29	7.72	9.26	0.58		54.5	8,429*
3	24	Starch—21,574 Bu. Corn	1 bu.	146.24	2.88	0.97	1.30	2.15	0.244	0.191	12.65	90,965
4	24	4 Small Meat Packers										
		Slaughtering—Hogs 1,563										
		Cattle 797										
		Sheep 34										
		Total 2,394	1 Animal	1470	10.8	4.88	1.52	7.2	1.2	1.8	42.3	25,674*
		Equiv. to 3589 Hogs	ditto	981	7.9	3.25	1.01	4.86	0.57	1.2	28.6	

* Corrected in the total to include other establishments of the same industry.

Indianapolis Industrial Waste—1934—Continued

Period of Observation		Type of Industry and Volume of Work Done	Unit Used	Gallons per Unit	Pounds per Unit							Total Population Equivalent
					Solids		Oxygen		Organic Nitrogen	Ether Soluble	Population Equivalent	
Days	Hrs. Day				Total Vol.	Susp.	Cons.	5 Day Demand				
4	24	1 Large Meat Packer										
		Slaughtering—Hogs....10,265										
		Cattle... 1,652										
		Sheep... 2,295										
		Total....14,212	ditto	845	7.15	3.29	1.37	3.88	0.48	1.09	22.8	81,071
		Calc. Hog Equiv........16,690	ditto	720	6.1	2.80	1.16	3.30	0.41	0.92	19.4	
		Total Meat Packers										
		Slaughtering—Hogs....11,828										
		Cattle... 2,449										
		Sheep... 2,329										
		Total....16,606	ditto	935	7.8	3.51	1.39	4.38	0.54	1.19	25.7	106,759
		Calc. Hog Equiv........20,280	ditto	766	6.4	2.87	1.13	3.58	0.44	0.97	21.0	
											Total	267,728
2	24	Paper Board—102.1 Tons Prod.	1 ton	36,000	147	144	34	18.2		8.89	107	5,478
2	24	Garbage Reduction—72.9 Tons Green Garbage..............	1 ton	194	42.8	4.3	33.4	57.2	1.6	1.2	336	12,271

15,700. This added to that of the cooker water is a total of 82,900 or 14.2 per cent of the 1933 population equivalent. These figures are for the extreme summer condition. In an average year the population equivalent of the cooker and condenser water is about 41,400 or about 7 per cent of the total from the city in 1933.

Most of these industries operate 24 hours daily except on Sundays and holidays but in almost all cases the daily load is far greater than that at night. The waste from the large packing plant carried 96 per cent of the total between the hours of 8 A.M. and 6 P.M. This accounts in great measure for the hourly variation reported in a previous paper.

Total Equivalent of Wastes.—The total population equivalent of the major industries is 267,728, which, added to the connected population, gives a total of 600,728, compared with a total population equivalent, as determined from the B.O.D. of the sewage for 1933, of 587,000.

With the advent of so-called sewer rental laws, serious consideration has been given to the matter of rates to be charged to producers of industrial wastes. Opinions of competent authorities vary from the extreme of making no charge, since the prosperity of a city depends on its industries, to the other extreme of making a full charge on the basis of B.O.D. of the wastes, it being contended that the disposal of byproducts is as much a part of the process as any other step in the manufacture or production of a finished article. In Indianapolis the cost of operating the sewage treatment plant is met by direct property taxation, with a negligible sum realized from a bank and building and loan tax. Applying the tax rate necessary to realize the actual 1933 sewage plant operation cost to the assessed valuation of the connected industries tabulated, shows that they paid a total of $878 for the disposal of their wastes for the year. On the basis of relative population equivalents, as determined from the B.O.D. results and volumes of flow, the treatment of the wastes from these industries cost $51,109. The large discrepancy in the two sums suggests that, in fairness to all industry and to individual tax payers, some middle course, at least, should be followed.

Conclusions.—1. Population equivalents were determined for nine types of industries, the total substantially accounting for the discrepancy between the enumerated population and the equivalent population calculated from the B.O.D. determination and the sewage flow.

2. A reasonable check was obtained with the packinghouse data previously reported by other investigators.

Editorial

DEWATERING DIGESTED SLUDGE

Until recently there has been no alternative to the use of outdoor sand beds for dewatering digested sludge. The outdoor bed remained the standard and sole type of dewatering device primarily because it was correlated in function with the Imhoff tank, which was designed to digest and store sludge through the winter and to discharge the sludge during the summer, when outdoor beds could be used to best advantage. Likewise there appeared to be no competitor to outdoor beds from the standpoint of economy.

With the great development of heated digestion tanks during the past five years, it has become possible to consider modifications of the outdoor sand bed. Heated digestors produce odorless digested sludge just as rapidly in winter as in summer, consequently long storage is not essential. It has therefore become possible to draw sludge to sand beds or other dewatering devices throughout the winter. In order to protect the drying sludge from the elements, glass covers have been installed, not entirely for providing winter drying area, but also for protection from rainfall in summer. This modification extended the possibilities of sand-bed drying, although the higher initial cost of glass-overs and differences of opinion concerning the relative capacities and costs of operation have limited the spread of glass-covered beds. It is surprising to note the differences in appraisals of the value of glass-overs. Mr. Jones, in this issue, gives information on open and glass-covered beds, and concludes that the glass-overs have demonstrated their superiority. His judgment is confirmed by Mr. Altemus, of Norristown, Pennsylvania, but Mr. Laboon states that after experience with installations of both types, he has come to the conclusion that the closed beds cannot be justified in efficiency and cost over the installation of the open beds. Similar conclusions have been reached at Springfield, Illinois, at the Calumet Works in Chicago, and elsewhere in Illinois.

There are certain factors, however, which usually indicate the necessity of covered beds, for example, small plants near high-grade residential districts, where it is essential to have some means of control for odors from occasional incompletely digested sludge, or from odorous scum. Covered beds, with artificial ventilation, provide a means of control impossible with open beds.

The choice of open or closed beds in general remains a matter of opinion, and even a study of some of the available data, as compiled by Mr. Jones, leads to no definite conclusion for or against closed beds.

The use of vacuum filters for dewatering digested sludge was a rather discouraging prospect because of expense five years ago, but improvements in filter design, increases in rates of production per unit of filter area, and lowering of the costs of chemical pre-treatment have greatly strengthened the apparent advantages of the vacuum filter, long recognized, but unavailable because of expense.

Mr. Jones offers comparative estimates of sand beds *vs.* vacuum filtration, but reaches no conclusion as to which is to be preferred from the standpoint of cost of operation. Similar comparisons have been made by Mr. Keefer, and he seems to note a definite advantage for mechanical filtration, particularly as a result of economy due to elutriation. Mr. Greeley has also compared vacuum filters and sand beds, with unfavorable conclusions for the former except for very large installations. Fltration preceded by elutriation was recommended for Washington, D. C., by Messrs. Eddy, Greeley and Gregory. Many similar comparisons are doubtlessly being made in other engineering offices, and installations of vacuum filters for digested sludge may soon be expected. Large-scale operating data will then be available to confirm or modify the information now available.

F. W. M.

HYGIENIC DISPOSAL OF SLUDGE

An appraisal of the infectivity of sewage sludge is bound to be disappointing from the epidemiological standpoint, therefore it may be desirable to attack the problem bacteriologically, as reported in this issue by Mr. Ruchhoft. His results indicate that a feeling of complacency is by no means justifiable when raw or wet sludges are permitted to be used as fertilizer on vegetables to be eaten uncooked. Further research on this subject is needed; the study of viability of B. typhosus in sludge should prove to be less complex by use of the improved media developed during the Chicago studies.

F. W. M.

Proceedings of Local Associations

CALIFORNIA SEWAGE WORKS ASSOCIATION
SEVENTH ANNUAL CONVENTION

Pasadena, September 5–6, 1934

The Seventh Annual Meeting of the Association was held at Pasadena, September 5–6, 1934, at the same time as the meeting of the American Public Health Association.

Many of the members arrived Tuesday night and had the pleasure of attending the Annual Hi-Jinks Dinner of the Public Health Engineering Section, A. P. H. A. Director Alexander Bell presided at the dinner which was featured by high-class entertainment and short talks by prominent sanitary engineers.

Wednesday, September 5

A caravan of about 40 cars assembled at the Maryland Hotel, Pasadena. Members and guests visited the Pasadena Activated Sludge Plant, serving a combined population of 124,000; the Beverly Hills Water Treatment Plant which softens, and removes hydrogen sulphide from, the well water supply; the Hyperion Screening and Incinerator Plant of the City of Los Angeles serving 1,130,000 population with average flow of 107 million gallons daily; and the Los Angeles County Sanitation Districts Activated Sludge Plant serving a large industrial area in addition to the domestic sewage of nearly 150,000 population.

Thursday, September 6

On Thursday morning a Joint Session was held with the Public Health Engineering Section, American Public Health Association, D. C. McMillan presiding. The first paper was "Experiences with Sewer Farming," by V. M. Ehlers, Chief Engineer, Texas State Board of Health. Western Texas is normally arid and land disposal is practiced by 69 cities, 34 having crops on a total of 4,500 acres. Successful crops are small grains, cotton and alfalfa. Rates of application vary from 4500 to 150,000 gallons per acre per day and revenues from $25 to $135 per acre. No raw sewage is placed on land. Four industrial plants use land disposal. If land is not overdosed there is no nuisance.

F. C. Roberts, Jr., State Sanitary Engineer of Arizona, continuing on the same subject, described the use of settled sewage effluent at Tucson where the flow from 32,000 population is spread on 200 acres out of a total of 1360 acres owned by the city. The unused acreage has been purchased from time to time from complaining neighbors and serves as a buffer area around the farm. He also described the disposal at Casa Grande where sewage effluent is chlorinated at a rate of 6 to 7 parts per million and disposed of on 25 acres at a rate of 6000 g.p.a.d. Total area owned by the city is 40 acres. A dose of 10 to 11 p.p.m. of chlorine is necessary to maintain a residual but 6 to 7 is enough to control odors.

E. A. Reinke, Senior Sanitary Engineer, California State Department of Public Health, summarized sewage farming practice in the state. The first sewer farm was bought in 1887. At present 90 communities have land disposal, 53 raising crops on a total of 3628 acres, chiefly fruit trees, vineyard and fodder crops. Regulations by the State Department of Public Health forbid use of raw sewage on growing crops, make no restrictions on use of well oxidized, highly disinfected effluents, and permit use of settled and undisinfected effluents on nursery and fodder crops.

"The Treatment and Disposal of Sewage in National Parks" was described by H. B. Hommon, Sanitary Engineer, U. S. P. H. S. The uniform policy followed has been to avoid contaminating streams or interfering in any way with use of streams for fishing or recreation, and to locate, construct and operate treatment and disposal plants so that they will not only be free of odors and any other nuisance but will conform to the high standards of the Park Service in relation to architecture and preservation of natural scenery in the parks. Arthur P. Miller, Sanitary Engineer, U. S. P. H. S., New York, discussed Hommon's paper and briefly summarized the work in the eastern division of the National Park Service, the outstanding feature being the successful handling without complaint of an estimated attendance of 100,000 in four days at the celebration of the Yorktown Sesqui-Centennial a few years ago. Large batteries of carefully attended and supervised pit privies combined with a can system on a public water supply watershed were used for sewerage facilities.

"Sea Outfalls and Ocean Disposal of Sewage in the East and the West" was the subject of a paper by A. K. Warren, Chief Engineer, Los Angeles County Sanitation Districts. Defining ocean disposal as discharge of raw sewage to the sea, he stated there were few cases of ocean disposal and in the future there would be a trend toward treatment of sewage before discharging it at sea. Fine screens have been frequently used in the past but at present sedimentation and grease removal are favored and at Ward's Island, New York, an activated sludge plant is under construction. S. A. Greeley of Greeley and Hansen, Chicago, sent a written discussion in which he stressed the importance of diffusion by multiple outlets and of taking advantage of currents. He stated that he had been over the Passaic Valley sewer outlet at times when no evidence of the discharge could be noted at the water surface.

Noon—An informal luncheon was held at the Hotel Maryland. Out-of-state guests were introduced by Secretary Reinke.

Afternoon—Members assembled at 2 P.M., D. C. McMillan presiding.

"Disposal of Wastes from Breweries" was the subject of a paper by Dr. A. M. Buswell, Chief, Illinois State Water Survey. The paper was read by Mr. LeBosquet of the Byllesby Engineers. Controlled fermentation of sugars in solution with utilization of gas produced was proposed.

Passing to the subject of Disposal of Wastes from Wineries, F. E. DeMartini, Junior Sanitary Engineer, California State Department of Public Health, read a paper briefly describing the procedure used in making wine, the character of wastes produced and present disposal methods. Heavier sediments, skins, seeds and particles of stems are removed as a "garbage-like material called pomace." This is usually hauled to neighboring vineyards for use as fertilizer. Lighter sediments deposited during the wine making process are called lees and may be made into cream of tartar or mixed with wine material, passed through the still and discharged with other liquid wastes. "Still slops," the residue from wine distilled for brandy, is a concentrated waste, the material from one ton of grapes being equivalent to sewage of about 225 persons. This waste is usually disposed of on land with varying success depending on the care used in handling. In a few cases it is discharged to streams and produces fungus-like growths for many miles below the outlet.

Walter A. Chowen, Manager, California Inspection Rating Bureau, discussed the subject "Establishing Insurance Rates for Sewerage Construction Work." He stated that the rates were based on experience, and the way to reduce them was to reduce accidents. California rates are based on a total payroll of $7,097,000. Medical attention and insurance for life to injured in some cases give astounding totals. One case cited had a medical bill of $39,000. The California rate is 11.36 per cent of the labor cost. This is 1.99 per cent lower than the national rate and lower than such states as New York, Michigan, and Minnesota. During the last three years the rate has been constantly decreasing. The California Sewage Works Association could help by stressing safety regulations.

"The Sewage Disposal Situation in Other States" was discussed by State Sanitary Engineers Boyce of Kansas, Roberts of Arizona, Green of Oregon and Harris of Washington. Boyce stated that in Kansas it was necessary for most of the cities to get water from contaminated streams. This condition and particularly the drought have brought about a demand for sewage treatment plants. The state law allows the city to order bonds without an election. The state is now making an investigation of oil pollution problems and charging the industry for the cost of the investigation. Roberts reported that in Arizona population was so scattered and climate so arid that land disposal was generally practiced. Septic tanks are the most common method of sewage treatment. Green stated that Oregon was in a position where most of the smaller cities were waiting for Portland to take the lead. After Portland builds a sewage treatment plant he expects many others will be constructed, chiefly along the Willamette River. Paper mill wastes are also a problem in Oregon. Harris of Washington stated that his state is divided into two parts, the western section bordering on Puget Sound where most of the population is concentrated, rainfall is adequate for stream flow and disposal by dilution without nuisance is possible. However, pollution of bathing beaches and contamination of shellfish growing areas are public health problems. The eastern section is high, arid and has only one large stream, the Columbia River. Pollution of other streams and use of water for irrigation indicate need of sewage treatment plants. Of thirty-four cities having sewage treatment plants, only one, that at Walla Walla, is modern.

F. A. Batty, Sewer Maintenance Engineer, City of Los Angeles, read a paper on "Incineration of Sewage Screenings at Hyperion." The screening plant has a capacity of 300 m.g.d. and present flow of 107 m.g.d. with an estimated contributing population of 1,130,000. Capacity of the incinerator is 50 tons of wet screenings per day, present amount being 30 tons per day. Operation cost is $1.22 per wet ton of screenings.

Reports of committees were read or discussed by the following members:

Membership—F. E. DeMartini.
Legislative—W. T. Knowlton.
  (Written reports by C. C. Kennedy and A. K. Warren were read by the Secretary.)
Publicity—Letter from A. G. Darwin, Chairman.
Licensing Operators—T. R. Haseltine.
  (Written report submitted by A. C. Beyer, Chairman.)
Safety Regulations—F. D. Bowlus.

These reports and that of the *Secretary-Treasurer* were accepted.

The Nominating Committee consisting of C. Froerer, J. H. Van Norman and G. Kjellberg presented its report and following additional nominations, the following were declared elected:

President—T. R. Haseltine.
1st Vice President—A. M. Rawn.
2d Vice President—E. A. Reinke.
Secretary-Treasurer—F. D. Bowlus.
Directors—J. F. Smith, F. A. Batty, Leon B. Reynolds, W. A. Allen, and A. G. Darwin.
Representatives to Board of Control—C. G. Gillespie and R. F. Goudey.

Mr. Goudey moved and it was seconded and carried that a vote of thanks be given to the retiring officers. President McMillan thanked officers and committees for their hearty cooperation during the past year and particularly the local committee for the Pasadena Convention—W. A. Allen, Chairman; A. P. Banta, M. J. Wesseler, and A. W. Wyman. He then turned the meeting over to the President-elect, T. R. Haseltine, who thanked the members for the honor and promised with the cooperation of the newly elected officers to carry on the work of the Association. The meeting adjourned at 5 P.M.

E. A. Reinke,
Secretary

CENTRAL STATES SEWAGE WORKS ASSOCIATION SEVENTH ANNUAL CONVENTION

Fond du Lac, Wisconsin

September 27–29, 1934

The Seventh Annual Convention of the Central States Sewage Works Association was held September 27 and 29, 1934, at the Hotel Retlaw, Fond du Lac, Wisconsin, with a total registration of ninety-three.

The meeting was called to order Thursday afternoon by President H. F. Ferguson, and the following papers were presented:

"The Chicago Combination Aerator and Clarifying Unit—Results of Tests at Monroe, Wisconsin," by Lewis H. Kessler, Asst. Professor, Hydraulic and Sanitary Engineering, and Philip F. Morgan, Research Assistant in Hydraulic and Sanitary Engineering. Prof. Kessler presented operating data of six months operation of the mechanical aerator installed at Monroe by the Chicago Pump Company. A satisfactory effluent was produced from an exceptionally strong raw sewage.

"Studies of the Longevity of B. typhosus in Sewage Sludge," by C. C. Ruchhoft, Bacteriologist, Sanitary District of Chicago. B. typhosus was inoculated into sludge and recovered up until 83 days. Typhoid bacteria were also isolated from uninoculated sludges. The results were made possible by improvement of the formula of the Wilson and Blair medium.

"The Population Equivalent of Certain Industrial Wastes," by C. K. Calvert, Supt., Indianapolis Sewage Treatment Works, and E. H. Parks, Industrial Wastes Chemist. Mr. Calvert pointed out the great inequalities between the amounts paid by industries for the disposal of their wastes and the actual cost of this disposal at the sewage treatment plant.

L. A. Guepel, Indiana State Sanitary Engineer, Indianapolis, Indiana, led a roundtable discussion on the method of scheduling and collecting service charges. This was followed by another discussion under the leadership of L. F. Warrick, State Sanitary Engineer, Madison, Wisconsin. Industrial wastes which caused operating difficulties in sewage treatment works and the corrective measures applied, were the subjects discussed.

The afternoon session closed with a paper by Wm. Lea, Assistant Chemist, and J. M. Holderby, Assistant Sanitary Engineer, Wisconsin State Board of Health, "Studies of Effect of Carbon-Nitrogen Ratio in B.O.D. Determination."

At 6:30 P.M. a banquet and entertainment sponsored by the Mayor and President of the Chamber of Commerce of Fond du Lac were enjoyed by all those attending. F. M. Dawson, Professor of Hydraulic and Sanitary Engineering at the University of Wisconsin and chairman of the Program Committee for 1933, made the presentation of awards. The award for the most excellent paper presented at the 1933 meeting went to F. W. Mohlman, Director of Laboratories of the Sanitary District of Chicago and Editor of the SEWAGE WORKS JOURNAL. The topic was "Recent Advances in the Chemical Treatment of Sewage."

Friday morning the first paper was that presented by O. J. Knechtges, F. M. Dawson and M. Starr Nichols, "Digestion of Mixtures of Domestic Sewage and Packinghouse Sludges." This work was done at Madison.

"Oxygen Resources and Utilization in the Upper Mississippi" was the title of the next paper by J. A. Childs, Sanitary Engineer, Minneapolis-St. Paul, Minnesota. This paper dealt with the Minneapolis-St. Paul sewage treatment problem.

A humorously instructive paper on "The Digestion of Garbage with Sewage Sludge" was presented by Professor H. E. Babbitt, Dept. of Sanitary Engineering, University of Illinois, and the morning session was concluded by C. K. Calvert and Don Bloodgood, Indianapolis, with their paper on "Active Sludge Operation Experiments." The data presented by them were of interest as showing what can be done by aeration without return of sludge.

After luncheon C. C. Larson, Chemist, Springfield, Illinois, Sanitary District, opened a roundtable discussion of bulking and other operating troubles peculiar to the activated sludge process. This was followed by the Question Box and discussion under the direction of L. F. Warrick. The discovery of an orange colored organism on filter beds, which seemed to counteract ponding, and the inoculation of ponding areas with this organism either mechanically or by return of a portion of effluent to the dosing tanks, were high points of the discussion.

At the business session the following officers were elected for 1934–35:

President, M. Starr Nichols, Madison, Wis.
First Vice-President, O. M. Leonard, Frankfort, Ind.
Second Vice-President, H. E. Babbitt, Urbana, Ill.
Secretary-Treasurer, Gus H. Radebaugh, Urbana, Ill.

Executive Committee

Lewis S. Finch, Ind.
Robert Cramer, Wis.
C. K. Calvert, Ind.
H. F. Ferguson, Ill.
F. W. Mohlman, Ill.
M. Starr Nichols, Wis.
O. M. Leonard, Ind.
H. E. Babbitt, Ill.
J. A. Childs, Minn.
Gus H. Radebaugh, Ill.

Representatives to Board of Control of the Federation of Sewage Works Associations

Robert Cramer, Wis.
H. F. Ferguson, Ill.
F. W. Mohlman, Ill.

Committee on Awards

C. K. Calvert, Ind.
B. Domomgalla, Wis.
W. D. Hatfield, Ill.

Membership Committee

L. A. Geupel, Ind.
H. F. Ferguson, Ill.
L. F. Warrick, Wis.

Local Arrangements

E. E. Smith, Ill.
H. E. Wilson, Ill.
W. A. Sperry, Ill.
W. D. Hatfield, Ill.

Program Committee

H. E. Babbitt, Ill.
O. J. Muegge, Wis.
E. C. Hurd, Ind.

Invitation Committee

C. C. Larson, Ill. Don Bloodgood, Ind.
Lewis Kessler, Wis.

Standardized Charge System for Sewage Service

H. F. Ferguson, Ill. W. D. Hatfield, Ill.
E. C. Hurd, Ind. C. K. Calvert, Ind.
E. J. Beatty, Wis. W. A. Peirce, Wis.
C. C. Wilbur, Minn.

Gus H. Radebaugh,
Secretary-Treasurer

EIGHTH OHIO CONFERENCE ON SEWAGE TREATMENT

Columbus, Oct. 4–5, 1934

The Eighth Annual Ohio Conference on Sewage Treatment, held in Columbus October 4 and 5, 1934, was an entertaining and instructive meeting for the 123 registered members and guests. A paper "Separate Sludge Digestion," by W. B. Walraven, superintendent of sewage treatment, Springfield, Ill., included a description of the successful utilization of gas generated in digestion tanks, for power purposes in the Illinois capital. The moot subject "Balancing Sewage Solids" was capably presented by F. W. Jones of Cleveland, and was followed by spirited discussion.

B. F. Hatch, assistant engineer in the State Department of Health, in a paper "Sealing Abandoned Coal Mines," explained in detail the work being done in Ohio to clean up streams now grossly polluted by mine drainage. Chemical aspects of the mine-sealing work were outlined by R. D. Scott, chief chemist in the departmental laboratories.

L. R. Howson, Chicago, was after-dinner speaker at the evening session the first day of the conference, and made an enlightening presentation of "Recent Trends in Sewage Treatment." He outlined the advances made in mechanization, tending toward greater efficiency, and the appreciable progress made in the elimination of odors at treatment plants.

One session was devoted to a round-table discussion of (1) sewage chlorination, (2) laboratory technique and control, and (3) marketing sewage sludge.

An innovation at this year's conference was a "gadget" competition. Devices made by plant operators and attendants to facilitate operation were entered and prizes awarded. Twenty-one devices were entered, and in the voting by members all except one received one or more votes. First prize was won by M. W. Tatlock, Dayton; second by G. E. Flower, Cleveland; and third by O. C. Lantz, Dayton. This feature was so popular that it will be repeated at the next conference.

Officers elected for the coming year are: W. P. Lockhart, Fostoria, chairman; G. A. Hall, Norwalk, vice chairman; A. H. Fretter, Medina, secretary-treasurer; R. E. Burnett, Marion, member executive committee.

NEW YORK STATE SEWAGE WORKS ASSOCIATION FALL MEETING

Oneonta, N. Y., October 5–6, 1934

The New York State Sewage Works Association held its Fall meeting at Oneonta, N. Y., October 5–6, 1934. President E. B. Besselievre presided. One hundred and eleven members and guests, including 14 ladies, were registered. The association was especially fortunate and honored in having as its guest Dr. Ernest John Hamlin, City Engineer of Johannesburg, South Africa. Dr. Hamlin spoke briefly at the luncheon and again in the afternoon, giving an interesting account of the sewage disposal problems in his city.

During the general business meeting there was a discussion on the subject of "Rating of Sewage Treatment Works." This was opened by Wellington Donaldson, who read a letter from C. A. Emerson, Chairman of the Federation of Sewage Works Associations, and followed this by some brief remarks on the proposed method of rating. After considerable discussion the following resolution was adopted: "Resolved that a standing committee of three members, to be known as the 'Rating Committee,' be appointed, the Chairman to be a representative of the Division of Sanitation, State Department of Health. It shall be the duty of this committee to make a report to the January, 1935, meeting of the N. Y. S. S. W. A. recommending a system of ratings for sewage treatment plants, based on the adequacy of operating data and records, irrespective of size of plant or type of treatment."

Morris Cohn, sanitary and testing engineer of the city of Schenectady, presented a very interesting and prophetic paper on "Combined Disposal of Garbage and Sewage." In his discussion of this paper Mr. Glenn D. Holmes, consulting engineer of Syracuse, referred to his plant-scale experiments for the grinding and disposal of garbage with sludge of the city of Syracuse. F. Wellington Gilcreas, associate sanitary chemist, New York State Department of Health, gave a very interesting and helpful talk on "The Significance of Laboratory Tests in Plant Operation."

At the luncheon the Honorable F. H. Marx, Mayor of Oneonta, cordially welcomed the convention to Oneonta.

Four papers were presented at the afternoon session. Dr. A. J. Fischer of the Dorr Company, New York City, spoke on "Recent Sewage Treatment Practices in Europe" as gleaned from his recent trip to Europe. Dr. Ernest John Hamlin then spoke on the unique problems in sewage disposal that confronted them in Johannesburg, South Africa, and gave a fine picture of the splendid *esprit de corps* that was developed in his staff by having weekly conferences on operating problems. A very successful symposium was held on the "Use of Sludge as Fertilizer" and considerable valuable information was interchanged. Abraham Slavin, associated with Clyde Potts, consulting engineer who designed the sewage treatment works of the city of Oneonta, described the plant, and Mr. M. C. Fleming of the Hardinge Company described special features of the mechanical equipment. Mr. Frank Gurney gave a very concise and interesting account of construction difficulties and unusual accomplishments. W. W. Watkins, Superintendent of the Bureaus of Water and Sewage Disposal, Oneonta, presented an interesting paper on the "Operation of Oneonta Sewage Treatment Plant," which was installed less than a year ago, and Mr. E. A. Bell of Clyde Potts' office gave an interesting and amusing paper on the operation of the plant during the tuning-up period.

In the evening the association enjoyed a clam bake, entertainment and dance at the Elks Club, including a dance revue by a local dancing class and several numbers by the Elks Glee Club. Through the courtesy of the City Board of Public Service and under the guidance of Mrs. F. J. McGuinness and Mrs. W. W. Watkins, the ladies enjoyed a very interesting trip to various places of historical interest in and around Cooperstown on Friday afternoon.

At the Sunrise Breakfast on Saturday morning a record attendance was announced for this famous event. Following a brief talk by Dr. R. D. Champlin, District State Health Officer, on "The Health Officer and Sewage Works Association" and the presentation of resolutions by the resolutions committee, Mr. C. C. Agar of the State Health Department opened the Question Box. The Round Table discussion answered many operating problems and gave much food for thought.

Following this an inspection trip was made to the Oneonta sewage treatment plant, which is of the separate sludge digestion type and has many unique features. The plant is well isolated and excellently laid out.

The next meeting of the association will be the 7th Annual meeting and will be held in New York City January 15, 1935.

A. S. Bedell,
Secretary

NEW ENGLAND SEWAGE WORKS ASSOCIATION SIXTH ANNUAL MEETING

Providence, R. I., October 15, 1934

The Sixth Annual Meeting of the New England Sewage Works Association was held at the Providence-Biltmore Hotel on Monday, October 15, 1934, with eighty-three members and guests registered for the various sessions of the meeting.

Displays of sewage works equipment were presented by the following manufacturers.

Lord and Burnham,
Wallace and Tiernan Co., Inc.,
The Norton Company,
Link-Belt Company,
The Carborundum Company,
The Dorr Company,
The Merrimac Chemical Company,
The Oliver Filter Company.

As always, these exhibits, which were arranged in the meeting room, proved to be a source of much interesting and useful information to those in attendance.

At 10:30 A.M., President Bugbee called the business session of the meeting to order. As the first item of business, he announced that a Nominating Committee consisting of Messrs. Kingsbury, Giles, and Wuraftic had been appointed and would report during the business session. The Treasurer reported a balance in the treasury, as of October 1, of $315.74, deposited in the Boston Safe Deposit and Trust Company. The Secretary's report showed a total membership of one hundred and thirty, a net loss of six over the previous year, the highest total membership of the Association having been reached in 1932 with one hundred and forty-one members. The Secretary also reported the deaths of two members during the year—Mr. Joseph Girouard of Spencer, Mass., and Mr. C. A. Griffith of South Manchester, Conn.

The President announced that an invitation had been received from the New York State Sewage Works Association to hold a joint meeting in the fall of 1935 at Schenectady, N. Y. He then called on Mr. E. B. Besselievre, President of the New York State Sewage Works Association, to extend the invitation in person. Mr. Besselievre explained the plans for the meeting which would be a two-day meeting to be held on a Friday and Saturday in October. Mr. Morris Cohn of Schenectady, Vice-President of the New York State Sewage Works Association, also spoke and expressed the hope that the two Associations might meet in his city. Following a general discussion, it was voted to authorize the Executive Committee to accept the invitation and to make all the necessary arrangements for the joint meeting.

The Nominating Committee presented its report and nominated for the consideration of the Association the following for the various offices.

President—Gordon M. Fair,
Vice-President—Guy E. Griffin,
Secretary-Treasurer—F. Wellington Gilcreas,
Director—Stephen DeM. Gage,
Director—Walter E. Merrill.

It was voted that the report be accepted and the nominations closed. The Secretary was instructed to cast one ballot for the nominees. This was done and the above officers declared elected.

At the suggestion of the Executive Committee, it was voted to appoint a Standing Committee on Membership. President Bugbee appointed Messrs. Van Kleeck, Sterling, and Johnson to serve as a committee.

Following the adjournment of the business meeting, President Bugbee introduced Mr. Charles C. Agar who presented the first paper, "The Use of Mechanical Equipment in Sewage Treatment." The second paper, "Pollution Load from Textile and Other Wastes in Proposed Rhode Island Metropolitan Sewer District," was presented by Mr. Stephen DeM. Gage. Dr. G. P. Edwards presented the third paper, "Recent Progress in Activated Sludge." Following a discussion of these papers, the meeting adjourned for luncheon at the Providence-Biltmore at 12:30 P.M.

At the luncheon, the Honorable James E. Dunne, Mayor of Providence, spoke and welcomed the Association to Providence.

Following luncheon, the Association gathered for the Question Box discussion. Before opening the Question Box, President Bugbee introduced the representatives of the manufacturers presenting displays and asked each to describe briefly his exhibit. The Question Box yielded a supply of questions and a profitable hour was spent in discussion.

Following the Question Box discussion, the meeting adjourned to the Providence sewage treatment plant where an opportunity was given to inspect the present plant. Mr. Bugbee explained the plans for reconstruction of the plant for the activated sludge process.

During the latter part of the afternoon, an inspection trip was also made to the combined sewage and waste treatment plant at the Sayles Finishing Plants at Saylesville, R. I.

The Annual Dinner of the Association was held at the Providence-Biltmore Hotel at 6:30 P.M. Following the dinner, President Bugbee introduced Mr. Charles A. Maguire, Commissioner of Public Works of Providence, who spoke briefly on the plans for reconstruction of the present plant and the use of the activated sludge process.

The address was presented by Mr. C. W. Mowry of the Associated Factory Mutual Fire Insurance Company of Boston who gave a most interesting and instructive talk on "Fighting Fires Beforehand," illustrated with lantern slides and demonstrations.

The meeting adjourned at 9:30 P.M.

F. Wellington Gilcreas,
Secretary-Treasurer

Book Reviews

Handbook of Chemistry. By N. A. Lange. Handbook Publishers, Inc. Sandusky, Ohio. Fabricoid, $6.00. This handbook of 1545 pages is filled with valuable information not only for the analytical chemist, but also for the scientifically trained man in all branches of chemistry, physics or engineering. Nowhere in one book in English, in the writer's experience, can be found the variety of tables, formulae, analytical data and mathematical constants presented in this work. The material is selected to make available quickly all data on physical or chemical phenomena likely to be desired by the user, without the complexity or expense of such volumes as International Critical Tables.

In addition to the usual physical and chemical data relating to organic and inorganic compounds, the handbook contains chapters on almost every conceivable subject of interest to the practical chemist, such as directions for first aid, composition and properties of anti-freeze solutions, formulas of laboratory solutions, properties of ceramic materials and materials of construction, tables of analyses of water supplies, coals and foods, mathematical tables, tables of physical constants, and a great variety of facts relating to miscellaneous physical, chemical and biological phenomena.

With this book, the sewage works chemist can feel secure in having at his finger tips almost all information likely to be desired in the course of his daily analytical work. Furthermore, the concise and accurate text relating to various subjects such as hydrogen-ion concentration, properties of the elements, definitions of chemical terms, pharmaceutical preparations, analytical procedures, etc., invites study by all chemists who wish to review, from time to time, the basic facts of their chosen science.

F. W. MOHLMAN

Sewage Pumps and Pressure Mains. Monograph II, Sewage Group, *Deutsche Gesellschaft für Bauwesen.* R. Oldenbourg, Schliessfach 31, Munich 1, Germany. Paper, 2.5 Marks. This second monograph of the Sewage Group of the German Construction Society comprises 17 pages, devoted to a discussion of various types of pumps and pressure mains for sewage pumping. Advantages and disadvantages of various types of pumps are listed, also efficiencies and operating costs. Airlifts are considered suitable for raw sewage up to 2.5 cu. ft. per second, but the efficiency is low (30 to 40 per cent). Pneumatic ejectors can also be used up to about the same capacity as air-lifts, and with equally low efficiency. Centrifugal pumps can be built up to large capacities and with efficiencies around 75 to 80 per cent, but large solids must be screened out of the influent. Reciprocating pumps are sometimes used up to 8 cu. ft. per sec., with very high efficiencies (80 to 85 per cent).

The properties of these types of pumps are discussed, also the factors which lead to choice of a particular type.

Following the discussion of pumps there is a short chapter on type of drive, including electric motors, Diesel, gas and gasoline motors and steam engines.

Three pages are devoted to a presentation of the formulae for flow of sewage in pressure lines, with a chart showing loss of head, flow and velocity in piping of various diameters.

This monograph was worked up under the direction of Director Götze of the Berlin department of public works, and prepared for publication by Dr. Ing. Heilmann.

F. W. Mohlman

Reviews and Abstracts

THE IMPORTANCE OF ARTIFICIAL LAKES FOR MAINTAINING THE PURITY OF THE RUHR RIVER

BY DR. F. SIERP AND PROF. DR. HAYO BRUNS

Gesundh. Ing., 57, 199, 1934

The Ruhr River furnishes the water supply, removes the sewage and provides recreation for the Rhenish-Westphalian industrial district. Since its use as a water supply is most important it is necessary to purify the sewage to a high degree. Only a few of the treatment plants of the Ruhrverband give complete biological treatment. Instead of equipping all of the 75 plants for complete biological purification, which would be very expensive, the Ruhrverband intends to substitute impounded lakes in part for biological treatment. Eight of these lakes are planned and three have been completed: Hengstey, area 0.62 square mile; Harkort, 0.54 square mile; and Baldeney, 0.93 square mile.

Purification in these lakes takes place by sedimentation, by flocking out the iron compounds which aid settling and by biological action which takes place with the aid of light and oxygen taken from the air or produced by plants. The first lake built, the Hengstey, completed in 1928, lies below the junction of the Ruhr and the Lenne. The iron in the Lenne flocs out on mixing with the Ruhr water so that the first action in purification is chemical precipitation. Near the village of Hengstey are located the dam and a power plant which has three turbines, each with a capacity of 1500 h.p. per hour. For economical reasons, cheap night current is used to pump part of the water of Hengstey Lake to a reservoir lying 525 feet above the surface of the lake. At the time of highest energy demand the water flows back to the generator to produce valuable power.

With an average flow of 812 cubic feet per second the water in the lake had a detention period of 34 hours and with 1060 cubic feet per second a detention period of 36 hours. Experiments have shown that the sludge settles well when the velocity is not more than 18 inches per second but that with a velocity of 19 inches per second the settled sludge begins to be disturbed. The detention period of the water in the lake should be between 10 and 20 hours. Nine investigations of the Hengstey Lake were made during the period 1928–1932 and average of the results is shown in Table I. At the same time these investigations were made the sludge deposits on the bottom were measured and samples were taken in order to ascertain the amount and kind of sludge deposits. Most of the sludge came from the more heavily polluted Lenne. As is evident from the plankton measurements the sludge content in the lake was reduced on an average from 45 c.c. per cubic meter to 2.5 c.c. per cubic meter or about 94.5 per cent. Calculated from the weight of the plankton, the sludge content decreased from 2217 p.p.m. to 81 p.p.m. or 96.3 per cent.

TABLE I.—*The Effect of Hengstey Lake*

		Average
pH	Ruhr	7.39
	Lenne	6.86
	Inlet to lake	7.01
	Outlet of lake	7.05
Clarity in centimeters	Ruhr	34.6
	Lenne	13.1
	Inlet	20.9
	Outlet	34.1
Dissolved oxygen p.p.m.	Ruhr	9.89
	Lenne	10.6
	Inlet	10.2
	Outlet	9.96
B.O.D. p.p.m.	Ruhr	1.52
	Lenne	1.5
	Inlet	1.78
	Outlet	0.77
Permanganate consumption p.p.m.	Ruhr	25.9
	Lenne	20.0
	Inlet	22.6
	Outlet	18.7
Total	Ruhr	3.9
	Lenne	11.2
	Inlet	8.9
	Outlet	3.3
Iron content p.p.m. Filtered	Ruhr	2.4
	Lenne	3.9
	Inlet	4.3
	Outlet	2.2
Volume c.c.	Ruhr	6.7
	Lenne	52.3
	Inlet	44.7
	Outlet	2.5
Plankton content per cubic meter Weight grams	Ruhr	178.0
	Lenne	1714.0
	Inlet	2217.0
	Outlet	81.0

Total	Ruhr	41900
	Lenne	26300
	Inlet	45470
	Outlet	23100
Bacteria per c.c. Coli on Endo agar	Ruhr	60
	Lenne	27
	Inlet	55
	Outlet	21

The iron content was reduced in the lake from 8.9 p.p.m. to 3.3 p.p.m. or about 63 per cent. Investigations showed that the storage of the water in the reservoir had no effect on purification. A large amount of sludge, deposited in the upper Ruhr during the years of low water, 1929–1930, was washed out by damming up the river temporarily and then allowing it to flow all at once down into Hengstey Lake, where the sludge all deposited. Removal of the sludge by dredging was not successful but the sludge could be removed by forcing it up into a barge and then drawing it off onto the lower lands. The plan of retaining the sludge in the lake and once a year, during high water, allowing it to flow to the Rhine and from there to the sea, proved feasible.

An unsuccessful attempt was made to recover the iron which amounted to about 40 per cent of the dry sludge. The high iron content prevented the use of sludge for fertilizer so that it could be used only for fill. The reduction in the permanganate consumption and especially the decrease of 57 per cent in the oxygen demand indicate the chemical-biological action of the lake. The increase in carbon dioxide in passing through the lake was not appreciable. The total bacteria count was reduced in the lake from 46000 to 23000 per c.c. or about 50 per cent while the Coli concentration was reduced from about 55 to 21 per c.c. or almost 60 per cent. This reduction is due to sedimentation and to consumption by the higher organisms which grow under the influence of light and oxygen.

Since a good stock of fish plays an important part in the self-purification of a river, the Ruhrverband had stocked the lake with eel, carp, tench, perch and whitefish. Investigations have shown that the whitefish and perch have grown very well and several carp which have been caught weighed more than seven pounds. Each year about 50,000 eels have been added and although little is known as to the action of these, eels are considered helpful in the removal of the sludge resulting from dead plants. No fishing has been allowed in the Hengstey Lake for the last five years but now the fishing rights have been sold to a fishing club. Conditions have greatly improved in the Ruhr below the lakes and adding rainbow trout to this section of the river is being considered.

G. P. Edwards

THE CENTRIFUGAL SCREEN

By Dipl.-Ing. Wilhelm Seegert

Gesundh. Ing., **57**, 68, 1934

The Zentri-Sieb (German patent) is a drum screen arranged centrally around a stationary vertical shaft and rotated by electrical power at a speed greater than that of the sewage. The surrounding walls are so designed that the sewage develops a circular motion as it flows around the moving screen. Centrifugal force keeps the solids away from the surface of the screen but if, for example, paper particles fall on the screen the whirling motion lifts them off. The solid particles work out to the outer edge of the water and flow back into the raw sewage. The circular motion in the spiral intermediate room forces the sewage through the screen and the sludge into the raw sewage. With an increased amount of water in the diluting body less purification of sewage is generally needed and the openings of the screen can therefore be made larger with increased screen loads to permit larger flows of sewage. The screen is movable, only a small amount of electrical power is necessary, the construction is simple, stable and it dispenses with all wearable parts. The large usable surface of the screen cannot become worn because it washes itself clean without any mechanical aid. The operation is easily visible and requires no special attention. The screen openings become larger with the increased height of the screen so that the diameter can be made smaller than with other types of construction. The height of the drum screen is to be so limited that when a definite height of water is reached in the diluting body the sewage flows over the upper edge of the drum, unpurified. With the screen open at the top the flow of the sewage is never stopped.

G. P. Edwards

THE CLARIFICATION OF POLLUTED WATER, WITH PARTICULAR REFERENCE TO COLLIERY WASTE AND SEWAGE

Paper by R. D. Gifford in the July, 1934 issue of the *Junior Institute of Engineers*.
Reviewed in *The Surveyor*, **86**, 349 (October 12, 1934)

This very interesting paper describes a process for the rapid settlement and dewatering of sludge developed by Mr. R. A. Henry of Liege, Belgium, and adopted for the treatment of the sewage of Micheroux, a city of 100,000 population. The inventor was primarily interested in the clarification of colliery waste waters and during extensive research found that the addition of a few drops of potato starch solution and caustic soda increased appreciably the rate of settlement of the suspended matters. Further investigation disclosed that to obtain rapid settlement the waste had to be slightly alkaline and that the starch grains had to be frozen before being used. Addition of the reagents in the exact proportion and in the correct way were found essential.

It was found that best results were obtained when the waste liquor was at pH 11, which is obtained by the addition of lime water or, in large installations, adding quicklime to the coal in the washer; in the case of sewage the lime is ground in the liquid.

The most notable feature of the Henry process is the use of frozen starch. There is as yet no satisfactory explanation of why freezing increases the efficiency of this coagulant. The dry starch grains are cooled somewhat below 32° F. in a container inside a refrigerator. One ounce of starch is sufficient for the treatment of about 1000 gallons of water.

It is imperative that the lime be thoroughly incorporated with the water. Because of the low solubility of lime it should preferably be ground under water so as to be subdivided into minute particles which will present a relatively large surface to the water. At Micheroux, a special lime grinding plant has been installed in the sewage treatment plant. The quantity of lime required is small and in coal washing waste the dried sludge recovered has a high fuel value and, therefore, permits a good return over the cost of chemicals. This sludge has the valuable property of rapid filtrability.

Practical Operation.—The slurry water, in practical operation, is thoroughly mixed with caustic soda and starch as it is pumped to a cone-shaped tank 30 ft. in diameter and 30 ft. deep. Immediate precipitation occurs, the solids passing out at the bottom of the tank to a special type of rotary vacuum filter, which reduces the moisture content to a residual of from 16 to 20 per cent. This coke is at once useful for fuel. The clarified water is said to be as clear as tap water, and has a transparency of 83 per cent as compared with distilled water after 3 minutes settling.

Cleansing of Polluted Rivers.—Mr. Henry next turned his attention to the cleansing of polluted rivers of Belgium, in which are large sludge deposits. A large scale experiment on the river Vesdre has been very successful and it is stated that an official Belgian commission is at present engaged upon the examination of a large project for river purification.

Sewage Treatment.—The works at Micheroux indicate the favorable possibilities of the Henry process in the field of sewage purification. The notable features of these works are the arrangement of the lime crushers in the sewage channels, the lime settlement of the sludge, the immediate removal of the sludge and scum to a conical settling tank where rapid concentration is effected by the use of frozen starch and caustic soda, and the dewatering of the sludge by vacuum filtration.

J. K. Hoskins

SEWAGE DISPOSAL AT MOTHERWELL AND WISHAW

Anon.

The Surveyor, **86,** 331–32 (October 5, 1934)

The new sewage treatment plant of the burgh of Motherwell and Wishaw, having a capacity of 2 m.g.d., was opened October 4, 1934. The new works, which cost £75,000, were designed to afford a maximum degree of flexibility of treatment. Among the notable features provided are special treatment and purification of storm water, the production of clean grit, mechanical agitation of sewage into which air bubbles have been blown and the utilization of sludge gas.

Storm Water Treatment.—Storm water is screened and grit removed from the total flow up to six times the dry weather volume and then passed to two storm tanks of the diffused air, activated sludge type, where it receives treatment and is then automatically discharged to the main treatment plant. These storm tanks are also used as balancing tanks with the dry weather flow and at such times provide a detention period of three hours. The bottoms are of the ridge-and-furrow type. Under normal conditions the flow through the storm tank is concentrated in a self scouring channel but when the flow exceeds this quantity the sewage level in the tank rises and fills other channels and when over three times the dry weather flow, the sewage overflows into the main body of the tank. If, after the storm tanks are filled, the flow still exceeds three times that of the dry weather rate, it will overflow at the effluent weir. Sewage retained in the tanks following a storm is automatically discharged to the main plant.

Features of the main plant include:

Screens.—Two screens, one mechanically and the other—a standby—hand cleaned, are composed of wedge shaped bars with 1–1½ inch openings. The mechanism for cleaning is automatically put in operation by a float controlled motor.

Grit Chamber.—This tank, 20 ft. square and 4 ft. deep, is mechanically cleaned. The grit is also separated from the organic solids by mechanical means and the organic sludge is returned to the incoming sewage.

Primary Settling Tank.—A detention period of 3½ hours is provided by a tank 70 ft. square and 11 ft. deep. The settled sludge is scraped to the center by a slowly revolving mechanism and pumped to the digestion tank.

Aeration Tanks.—These tanks are 150 ft. by 130.6 ft. in plan and 11 ft. deep and provide about 10 hours detention. They are provided with longitudinal air diffusers on the ridge and furrow principle and with paddles which cause a circulating movement and thereby increase the time of contact of the sewage with the diffused air.

Final Settling Tank.—The final settling tank is 85 ft. square and 11 ft. deep, similar in design to the primary tank, and holds about 6 hours flow. The settled activated sludge is pumped to the inlet end of the aeration tanks, the surplus going to the primary settling tank.

Digestion Tank.—Sludge is digested in an insulated tank 60 ft. in diameter and 27 ft. deep, with a capacity of 68,000 cu. ft. The digesting sludge is stirred by a special, slow moving mechanism and is held at 80° F. by means of hot water coils. The raw sludge is introduced at the top and the digested material drawn from the bottom.

Gas Production and Utilization.—Gas is collected in domes in the digestion tank roof and stored in a 5,000 cu. ft. holder. The total power required for sewage treatment amounting to from 60 to 70 h.p. is readily supplied by part of the gas produced. The exhaust engine gases are used to heat the circulating water for the digestor tank coils.

Sludge Beds.—These beds are underdrained and consist of 9 inches of 1–1½ inch broken stone, 6 inches of screened coarse hard ash, topped with finer material. They have a total area of 44,000 sq. ft. or about 1.5 sq. ft. per capita. The seepage is pumped back to the works for treatment.

J. K. Hoskins

THE EXPERIMENTAL STATION AT FOGGIA FOR THE PURIFICATION AND UTILIZATION OF SEWAGE IN THE FIRST TWO YEARS OF ITS EXISTENCE

By Girolamo Ippolito

Fondazione Politecnica del Mezzogiorno, Monografie Techniche, Napoli, 1934

The experimental plant described in this volume of 157 pages was built by the Apulian Aqueduct Commission to investigate sewage treatment processes for all sewage treatment works planned or under construction and to prepare skilled managers for these plants. It is the first plant of its kind in Italy and has been laid out carefully and built substantially. Construction started in 1929. The present report gives a full description of the plant and the operating results for the period of August, 1931 to October, 1933. The plant uses part of the sewage from the outfall sewer of the separate sewerage system of the City of Foggia, which is located about 100 miles east of Naples and has a population of about 65,000.

The plant consists of the following units:

(1) A diversion chamber with vertical dividing wall in the interceptor.
(2) A mechanical (Dorr) screen with 1 in. openings.
(3) A Lea recording hydrograph.
(4) Two centrifugal pumps for raw sewage with 210 gal. per minute capacity.
(5) Two circular Imhoff tanks, one with a diameter of 17 ft., 8 in. and a depth of 29 ft., the other with a diameter of 21 ft. and a depth of 22 ft.
(6) A plain settling tank, 19 ft. long and 6 ft., 4 in. wide, with 4 ft. depth of the flow chamber and with three hoppers 6 ft., 6 in. deeper.
(7) Two separate sludge digestion tanks, each with a diameter of 15 ft. and a depth of 19 ft., with fixed submerged covers for gas collectors.
(8) Four sludge drying beds, each 33 ft., 3 in. by 13 ft., 3 in., and a sludge lagoon.
(9) Two circular trickling filters with a diameter of 23 ft. and 6 ft. depth, with rotating arms and final sedimentation tanks.
(10) Two compressed air activated sludge plants, one with one channel 6 ft. by 6 ft. and 29 ft. long, and possibility to reaerate the return sludge; the other with three channels, each 4 ft. by 4 ft. and a length of 13 ft. for partial treatment. Both these tanks have aeration of the Hurd type and paddles of the Essen Rellinghausen type. Both have identical secondary settling tanks of the Dortmund type.
(11) Mechanical aeration is represented by a small Simplex aerator, 6 ft. in diameter and 7 ft. deep.
(12) Two contact aerators, each with a cross section 3 ft., 3 in. by 3 ft., 3 in., one 4 ft. long and the other 12 ft. long, with final settling tanks also of the Dortmund type.
(13) A chlorinator, Ornstein type, to be used for deodorization, for clogged filter beds or for experiments on sterilization.
(14) Sludge pumps from secondary sedimentation tanks to the plain settling tanks and to pump the effluent of the drying beds to the inlet.

(15) A building containing complete chemical and bacteriological laboratories and rooms for the administration and for instruction.

It is planned to build an additional circular filter and a rectangular filter with fixed nozzles, a Sheffield aeration tank, a gas tank, and heating facilities for the separate sludge digestion tank.

All the tanks are built of reinforced concrete, but arranged to allow changes for experimental purposes.

Such a plant requires careful control of tests, if the results are to be of value. Samples of 250 c.c. were taken four times a day on the raw sewage, also the content of activated sludge tanks and effluents of every unit in operation according to a time schedule to give representative daily composite samples, weighed relative to the flow and to correspond to the same rate of inflow and outflow of each unit. Of the daily samples, 200 c.c. were put in 1500 c.c. bottles to get a weekly composite sample. All these samples were kept on ice for preservation.

Daily meteorological observations were made and measurements of the total flow and of the flow through each unit and of the temperatures therein. On the daily sample tests were made for settleable solids in 30 minutes and 2 hours and on effluents for the relative stability with methylene blue. Complete analyses were made on the weekly samples, including settling solids, suspended, dissolved and total solids, oxygen consumed, dissolved oxygen, B.O.D. by the Sierp method, chlorides, pH value, ammonia, organic, nitrite and nitrate nitrogen and alkalinity. The tests for dissolved oxygen on the weekly samples seemed unreliable and were later made on the daily sample of all effluents. At irregular intervals tests were made on the content of the digestion tanks and of the sludge beds; also counts of total bacteria and of B. coli. Very often, usually several times a day, the activated sludge was examined microscopically.

The water supply and sewerage system of Foggia must be new, as the water consumption rose in the period 1931–33 from 380,000 gal. per day to 530,000 gal. per day and the number of house connections to the sewers from 1046 to 1926. About 90 per cent of the water consumption flows in the sewers. The maximum flow is 1.36 and the minimum 0.59 times the average flow.

The raw sewage is of domestic character, without industrial wastes. It has an average of settleable solids of 10.9 c.c. per liter, an average of 20-day B.O.D. of 523 p.p.m. The 5-day B.O.D. was found to vary from .232 to .561, with an average of .411, of the 20-day B.O.D. and not .68, as it should theoretically be. (*Editor's Note:* Evidently a misunderstanding of the B.O.D. curve, since 5-day is not supposed to be 68 per cent of 20-day, but 68 per cent of *first stage.*) It is therefore recommended that the 5-day B.O.D. be used with care. The analyses of daily samples show much greater values except for organic nitrogen than those of the weekly composite samples.

The oxygen consumed test is considered unsatisfactory for sewage. The B.O.D. test is considered to give much better information on the efficiency of a plant.

Tables give the results of the analyses of the weekly samples of the raw sewage and of the effluents of the different units. Average efficiencies, as measured in per cent of B.O.D. reduction, are given as follows:

Sedimentation	53.7%
Sprinkling Filters	83.5 to 90.3%
Activated Sludge	91.5%
Partial activated	89%
Simplex Aerator	92.5%

Data on many of the tests are given in tables and graphs. Some results and suggestions therefrom will be mentioned:

There was little improvement by prolonging sedimentation beyond one hour. The variations in removal were between 83 and 95 per cent for solids and between 60 and 68 per cent for suspended solids for different times of sedimentation.

Addition of formalin, which is not a coagulant but a disinfectant, to the effluent of final sedimentation tanks gave only ⅓ as much settleable solids as without the disinfectant. The sediment measured in the ordinary way in effluents is therefore probably mostly freshly formed by the action of the bacteria present and not all flowing over the weirs. A method to consider this in the calculation of efficiencies is tentatively outlined.

Every 1000 cu. m. of sewage treated gave 4500 liters of fresh sludge with 93 per cent water content, 1530 liters of digested sludge with 91 per cent water content and 540 liters of dried sludge with 35 per cent water content. These values are without the sludges from secondary treatment.

For the climatic conditions of southern Italy, it was found that a depth of 15 to 17 ft. in Imhoff tanks is sufficient. A sludge volume of 0.312 per cent of that of the sewage treated (per day) is sufficient for winter storage. An addition of fresh sludge amounting to 5 per cent of the digested sludge present in the tank is allowable even during winter.

About three times as much scum was formed in the Imhoff tanks as in the separate sludge digestion tank. (200 liters to 60 liters per 1000 cu. m.)

Under the climatic and operating conditions prevailing, the sludge dried in clear and calm weather in summer in 7 days and in winter in 10 days. Imhoff tank sludge reduced thereby to 35 per cent of its original volume and separate digestion-tank sludge to 30 per cent thereof. Eight fillings of the sludge beds are possible in the period from March to September and four fillings in the winter months from October to February.

Sludge storage capacity and sludge bed area should not be considered as separate problems. High sludge storage capacity allows reduction in sludge bed area and vice versa. Which one of these factors should be made large is a question of economical design and of the space available.

Only the first and third sprinkling filters were in operation. Both are circular filters, the first with Jones and Attwood spraying paddles and the third with drilled holes on the rotating arms. The first gave better results and caused less trouble in winter. The efficiencies in B.O.D. reduction were for the first filter 79 per cent and for the third 65.3 per cent. The specific capacity of the first filter was 1.5 cu. m. of stone for each cu. m. of sewage treated per day. This volume of stone was insufficient for the third filter. Unloading of the filters occurred only once per year, in April and May. No odors or mosquitoes developed in the bed, but a very small fly, which did not fly farther than several meters from the filter bed.

The final sedimentation basins provided 5 hours retention. They were overbuilt, but were intended for other experimental purposes. The sludge had to be removed four times per day to prevent it from getting acid. About 20 cu. m. of sludge, with a water content of 99 per cent, was deposited for every 1000 cu. m. of sewage flowing through the tank. This is about 4 to 5 times the volume of fresh sludge deposited in the Imhoff tank, but only about ⅔ of the content of dry matter.

Only the smaller of the contact aerators was used, and with unsatisfactory results. The B.O.D. reduction was less than 20 per cent in summer and about 50 per cent in winter. The sludge extracted was putrid and of bad odor, even though removed several times daily. Probably the climate of southern Italy is too warm for this type of treatment.

The tanks with contact aerators will be transformed into activated sludge plants of the Kremer or Kessener type.

Operation of the activated sludge plant was a constant fight against the bulking of the sludge. Eight times during the two years of the report, the tanks had to be emptied and new series started, always because bulking sludge formed that could not be revived. Many things were tried under careful chemical and biological laboratory control.

Different kinds of loadings, different proportions of air and of return sludge, reaeration of the return sludge, recirculation of the whole content of the tanks, all these were tried but nothing succeeded until the supernatant liquor of the separate digestion tank was kept out of the activated sludge process. The retention period in the aeration tank varied from 5 to 7 hours, the proportion of liquid to air from 1:1 to 1:11.5 and that of the liquid to the return sludge from 1:0.25 to 1:0.5.

In the second activated sludge plant, which was intended to give only partial treatment, little bulking occurred, as no supernatant liquor from the separate sludge digestion tank was added. But red chironomid larvae caused trouble each year during August and September. This was overcome by adding pyrethrum powder to the amount of 100 gr. for each cu. m. of tank content (1 lb. for 1200 gal.) in a single dose. The pyrethrum powder seems to have no effect on the protozoa in the activated sludge.

The Simplex plant with 7½ hours of aeration and 4 hours of sedimentation gave satisfactory results, yet not as good an effluent as the first activated sludge plant. The plant is considered a little too small for satisfactory testing, having a capacity of only 16 gal. per minute.

The quality of activated sludge can be judged from its rate of settling in a glass cylinder. Good activated sludge settles quickly and leaves a clear supernatant liquid, but after a few hours the sludge may rise to the surface. This happens more quickly with dense sludge and warm temperatures. Bad sludge sometimes does not rise until after standing a day in the cylinder. The floc is judged by its character and microscopical appearance, although it is often advisable to make determination of its water and volatile matter content. A safe index also indicates the dissolved oxygen content of the mixed liquor and of the effluent. The relative stability test gives results delayed 20 days. The sedimentation test should be standardized, so that it is read in 30 minutes or 1 hour. The station at Foggia adopted 30 minutes as a routine test and this should give 150 to 200 c.c. sludge per liter.

Normal sludge has about 99 per cent water, whereas in period of bulking up to 99.8 per cent water was found. Under good operating conditions about 23 cu. m. of sludge was formed from 1000 cu. m. of sewage treated. Good results were obtained with 6 hours of aeration, a volume of air at atmospheric pressure of 6 to 7 times that of the sewage and an amount of return sludge of about one-half that of the sewage. A large amount of thinned return sludge gave better results than small amount of concentrated sludge.

The question of the treatment of supernatant liquor from the separate sludge-digestion chamber was also studied. This liquor had a 20-day B.O.D. of 1200 to 1500 p.p.m. It was thought that this could be treated with the waste activated sludge, but it had a poisonous effect on the sludge. This may be the reason it caused so much bulking when introduced in the activated sludge plant. It was found that aeration of the supernatant liquor for one-half hour to eliminate some of its dissolved gases, then introducing the waste activated sludge and aeration for an additional four hours, reduced the B.O.D. of the liquid to 300 and 400 p.p.m., in which state it could safely be introduced into the sedimentation chamber.

Studies were made of the agricultural use of effluents and sludges on the tract adjoining the plant. Irrigation by the effluent of the oxidation units was compared with that by effluent of plain sedimentation and by clear water, with plots without irrigation as a control. Corn was raised on the fields. The effluent from plain sedimentation gave best results. Digested dried sludge was compared with fresh and matured stable manure and a mixture half manure and half sludge, in the effect on corn and garden vegetables. The results were so satisfactory that the farmers are asking to receive the sludge. In the second year the irrigation tests were repeated, but with better distribution of the water and all waters brought to the same nitrogen content by using ammonium sulphate. Even so, differences in effect were noticed.

It will be of interest to receive further reports of this sewage testing plant and the results of detailed research planned therein.

MAX SUTER

THE INFLUENCE OF THE PURIFICATION BY ACTIVATED SLUDGE AND SLUDGE DIGESTION ON THE BACTERIA OF THE COLI-AËROGENES GROUP IN SEWAGE

BY F. NERI

Annali d'Igiene, Anno **XLIV**, 1934

Report of an investigation made by the professor of hygiene of the University of Florence at the sewage testing plant at Colombe, near Paris, France. This testing plant was built by the City of Paris, to study the treatment of Paris sewage to replace the sewage farms.

The sewage of the City of Paris is settled at Colombe and pumped to the sewage farms. The testing plant can use fresh or settled sewage and has units of sprinkling filters and of activated sludge.

Professor Neri's investigation consisted of making total and coli-aërogenes counts on fresh and settled sewage, return sludge before and after reaeration, on the content of the last aeration basin (mixed liquor and activated sludge), on the effluent and on the digested sludge. The samples were taken mostly in the afternoon, kept on ice over night and plated next morning. The total count was made on agar at 37° C. after 48 hours. For the coli count, Professor Neri's special method was employed. In this method the cotton stopper of the sample bottle is replaced by a sterile cork stopper and the sample vigorously shaken. If the sample is sludge, it is diluted with 3 times its volume of physiological salt solution. A series of dilutions of each sample is prepared and of each dilution 1 c.c. is seeded in 10 c.c. of lactose broth with phenol-red, prepared as follows: to 100 c.c. of ordinary broth are added 10 c.c. of 20 per cent sterile lactose solution and 1 c.c. of 0.5 per cent phenol-red made up in 100 c.c. distilled water and 1.5 c.c. of normal KOH solution. Each solution is separately autoclaved and the dyed lactose broth prepared in sterile tubes before use. The seeded tubes are incubated at 37° C. and acidified (yellow) tubes are plated on lactose agar with phenol-red for the isolation of coli bacteria.

Neri found little removal of coli bacteria by sedimentation. The returned sludge and the mixed liquor of the aeration tanks contained from 2 to 10 times as many coli bacteria as the raw sewage, whereas the final effluent showed from 80 to 98 per cent reduction of B. coli. Digested sludge had sometimes only 1/50, sometimes 10 times as many B. coli per c.c. as the raw sewage. Digested sludge plated directly after sampling had more B. coli than that kept a few days.

The total count showed a reduction from 1/4 to 1/3 by sedimentation, a similar increase in the aeration tanks, 2 to 4 times as many in the return sludge, with a slight reduction by reaeration. The count in the effluent showed a reduction of from 96.9 to 98.6 per cent of the raw sewage count. The total count in the digested sludge was irregular, sometimes less than 1/2, sometimes more than 20 times as many in the raw sewage.

Professor Neri considers the main result of his investigation to be the establishment of the fact that the content of B. coli is much greater in the activated sludge and in the mixed liquor than in the raw sewage. From the results of investigations by Heukelekian and Rudolfs and by Arloing and Dufourt, he thinks that this increase is not due to growth, but to an accumulation from the flowing through sewage.

Digested sludge has a much lower content of B. coli. This indicates that these organisms have little multiplication, and therefore their participation in the purification process is limited. From a review of the literature, including the American, of the behavior of pathogenic organisms in sewage, he concludes that B. coli can be considered as an index organism and that the anaerobic digestion chambers can be looked on as a graveyard for pathogenic bacteria.

MAX SUTER

THE SELF-PURIFICATION OF STREAMS *

By M. Lundie

In this reprint the author gives a rather general discussion of stream pollution and purification with particular reference to the value of sewage treatment works in preventing stream pollution. He classifies streams into (1) very clean, those having a 5-day B.O.D. of less than 1.0 p.p.m.; (2) clean, from 1.0 p.p.m. to 2.0 p.p.m.; (3) fairly clean, from 2.0 p.p.m. to 2.7 p.p.m.; (4) moderately clean, from 2.7 p.p.m. to 3.1 p.p.m.; (5) doubtful, from 3.1 p.p.m. to 5.0 p.p.m.; (6) bad, from 5.0 p.p.m. to 10 p.p.m. or more. As a particular case he takes as an example the Aapies stream at Pretoria in South Africa and shows that with the installation of treatment works, consisting of screens, detritus channels, sedimentation tanks, dosing syphons, percolating filters, secondary filters, followed by impounding basins and chlorination, sludge digestion tanks and sludge drying beds, the stream will be converted from one that is "excessively bad" to one "fairly clean" at the point of discharge of the effluent and "definitely clean" a little lower down the course after the self-purifying agencies have had time to act.

The author also points out that inasmuch as no chemicals have been added, the effluent is still available and may be used for land irrigation and fertilization.

E. Hurwitz

THE SANITARY DISPOSAL AND AGRICULTURAL UTILIZATION OF HABITATION WASTES BY THE INDORE PROCESS

By F. K. Jackson and Y. D. Wad

Bulletin No. 1, 1934. Institute of Plant Industry, Indore, Central India

The Indore Process is essentially a thermophilic digestion of a mixture of habitation refuse and night soil. Attempt is made to prevent anaerobic bacterial action by spreading the night soil in thin layers over the refuse and by turning over the whole mass several times during the digestion period. The process requires from three to eight weeks, after which an innocuous mass remains which has some value as a fertilizing medium. The authors give in detail the technique for carrying out the process and make several claims of advantages for their process, among which are low capital outlay and operating costs and profitable return from the sale of the end product as fertilizer.

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* Reprint from the Minutes of the Proceedings of the South African Society of Civil Engineers.

This article was also published in *The Indian Medical Gazette*, Vol. LXIX, No. 2, February, 1934.

E. Hurwitz

TREATMENT OF LAUNDRY WASTES

By J. A. Boyer

Bulletin No. **42**, Agricultural and Mechanical College of Texas

Studies of the feasibility of chemical precipitation methods, trickling filters and Dunbar filters in the treatment of laundry wastes resulted in the conclusion that chemical precipitation methods, although producing a very good effluent, would be economically impractical and would require close technical control; the Dunbar filter gives a good effluent but offers objectionable operating difficulties; sprinkling filters are practical both from a cost and operating point of view.

In his experimentation with chemical coagulants the author found that unless the pH of the waste were adjusted from 9.0, its original H-ion concentration, to approximately 6.4 very large amounts of chemicals would be required. The amounts required for good precipitation with and without adjustment for the various coagulants used are shown in the following table:

	Ferric Sulphate	Ferric Chloride	Aluminum Sulphate	Ferrous Sulphate
pH not adjusted..........	400 p.p.m.	400 p.p.m.	520 p.p.m.	1000 p.p.m.
pH adjusted............	240 "	160 "	200 "	400 "

Approximately 0.5 c.c. of concentrated sulphuric acid per gallon was required for adjustment of the H-ion concentration. Starting with a raw waste of not more than 450 p.p.m. it is possible to obtain 85 to 90 per cent reduction in B.O.D. by this method.

The reduction in B.O.D. obtained with the Dunbar filter ranged between 65 to 80 per cent at a dosing rate of one m.g. per acre per day. However, clogging of the filter caused by the cementing together of the sand on the upper fine layer, made necessary treatment with caustic soda at intervals of three to six weeks and resting of the bed for eight hours after application of the alkali. This operating difficulty would necessitate the use of an additional bed and consequently cut the net dosage to one-half m.g. per acre per day.

The trickling filter operating at a rate of two m.g. per acre per day gave no operating difficulties and reduced the B.O.D. 72 per cent.

The investigation indicates that trickling filters because of their low cost of operation and their need for very little operating attention, are best adapted for use by laundries in the treatment of their wastes.

E. Hurwitz

THE SEWAGE TREATMENT PLANT AT CARLISLE, PENNSYLVANIA

By Elton D. Walker

The American City, **69**, 80–81 (Sept., 1934)

The new sewage treatment plant at Carlisle will be built on the site of the old plant with funds furnished from a P.W.A. grant. The plant will include bar screens, a screening digester, preliminary settling basins, separate sludge digestion tanks with Downes floating covers, glass covered drying beds, control house and laboratory, trickling filters with rotary distributors, a disinfection house, and secondary settling basin. The plant is designed to treat the sewage from a population of 17,100 with an average daily flow of 1.46 million gallons.

Details of the construction and dimensions of the various units, as well as their unique features, are given in the article.

E. Hurwitz

CHLORINATION AT THE SEWAGE TREATMENT PLANTS OF GREENWICH, CONNECTICUT

By Guy E. Griffin

The American City, **69**, 68–69 (Sept., 1934)

The Greenwich sewage treatment plants, four in number, are located at East Port Chester, Gross Island, Cos Cob, and Old Greenwich.

The East Port Chester plant was built in 1917 and consists of three septic tanks, chlorinating apparatus, and glass covered sludge drying beds. The Gross Island plant consists of ten Imhoff tanks, chlorinating apparatus and open sludge beds. It was built in 1918. In 1932 grit chambers were added. The Cos Cob plant, built in 1930, is made up of five septic tanks, chlorinating apparatus, and covered sludge beds. The Old Greenwich plant, consisting of three septic tanks and chlorinating equipment, was built in 1926. In 1932 the old sludge beds were rebuilt and two additional glass covered beds added. Bar screens with $1\frac{1}{2}$ inch openings and two plain sedimentation tanks and a sludge digestion tank with Downes floating cover were also added.

The effluent from these plants is chlorinated from approximately May 1 to October 1. Previous to 1932 chlorine was purchased in 100 lb. cylinders but in 1932 provision was made at all plants to handle chlorine in ton containers, thereby effecting a saving of about 59 per cent in chlorine costs and eliminating to a great extent the handling costs.

Prechlorination was tried at East Port Chester and Old Greenwich. At the former plant the experiment resulted in an increased chlorine demand, while at the latter a slight saving over post chlorination was effected.

E. Hurwitz

OPERATING RESULTS AT GALESBURG

By L. W. Hunt

Municipal Sanitation, 5, 296–298 (Sept., 1934)

During the year 1933, the first year of normal operation, the Galesburg, Illinois, sewage treatment plant treated an average of 2,475 m.g.d. The amount of material removed during the year by the coarse bar screens amounted to 50,000 pounds; grit 308,000 pounds; grease, oil and scum 42,000 pounds; fine solids removed in settling tank 670,500 pounds. This represents an average daily removal of 2,930 pounds of solids. The 670,500 pounds of fine solids pumped to the digester produced an average of 7.56 cu. ft. of gas per pound of solids. The gas is sufficient for all heating requirements during the winter months. Approximately 800 cu. yds. of dried sludge were produced and removed by the public as a fertilizer for lawns and gardens.

As measured by the B.O.D. 25.9 per cent of the oxygen demand of the incoming sewage was removed with the screenings, grit and settled solids. The sprinkling filter removed 45.9 per cent. The over-all efficiency of the plant was 71.8 per cent.

The only operating difficulty encountered was the pooling of the filter bed. This was corrected by turning over the upper six inches of stone.

The cost of treatment amounted to $22.50 per million gallons. On a per capita basis the cost was 70 cents.

E. Hurwitz

TWO YEARS' EXPERIENCE WITH THE PHOENIX ACTIVATED SLUDGE PLANT

By Percy E. Mauzey

Interesting points in the operation of the Phoenix, Arizona, plant are described in this abstract of a paper read before the Arizona Sewage Works Association.

The foaming of the digesters, which started a month or so after being put in service, continued about 8 months, but has given no trouble since. Temporary relief was obtained by liming to a pH above 8.5.

The thickener, used to concentrate a mixture of primary sludge, excess activated sludge and digester overflow, produced odors due to septic action and discharged septic floc to the primary clarifier. Liming to pH 8.5 or above permitted concentration of either or both primary and excess activated sludge without odors or scum. This tank has been more recently used to concentrate the mixed liquor, with satisfactory results.

Cannery wastes, "tomato seeds and peach scrap," caused bulking which was overcome by liming the aeration and re-aeration tanks. Phenolic wastes from a gas plant also caused trouble during the winter when these wastes are not used for irrigation. Manufactured gas is to be replaced soon with natural gas.

Mechanical difficulty has been experienced with the driving mechanism which rotates paddles against the air stream. Clogging of the porous plates caused by shutdowns has been lessened by brushing with a wire broom or a portable electric wire brush, and burning with an acetylene torch, or when emptying tanks by keeping a low air pressure and flushing with water. The suction caused by drawing sludge from the clarifiers through 185 feet of 8 inch pipe with several bends is undesirable and may be overcome by relocating the pumps closer to the clarifiers. Lack of a grit chamber has caused difficulty and is to be remedied by the construction of one. Settling of return sludge has been prevented by agitation with air through a 2 inch pipe with $\frac{1}{32}$ inch holes bored at 4 inch intervals. Rising stem gate valves are favored to retard corrosion.

Screenings are buried and the pits treated with borax to prevent fly breeding. Fly spray is used in the pump room and screen house. Plant effluent is to be used for irrigating the grounds, which are being effectively landscaped.

R. W. Kehr

EVALUATING THE COSTS OF SLUDGE DISPOSAL METHODS. DEWATERING ON VACUUM FILTERS VS. DIGESTION AND SAND BED DRYING

Water Works and Sewerage, Vol. **81**, No. 8, August, 1934

Part I. The Economics of Sludge Digestion, Dewatering and Disposal.

BY HARRY F. FERGUSON AND W. HOMER WISELY

To procure authentic cost data it was decided to tabulate and study the actual costs of digesting, drying and disposal of sludge in six well operated sewage treatment plants in Illinois. All of these plants, though they had different types of units, were using standard procedure of digestion and sand drying followed by final disposal of the sludge cake as fertilizer or for filling purposes.

The cost of digesting, drying and disposing of sludge at any treatment works is dependent on the solids in the sewage and upon the efficiency of the equipment installed. Design and operating data are given for each of the plants studied. The design data show wide variations in available capacities of the digestion, storage and drying units. It was originally planned to adjust these capacities to a common standard unit for digestion tanks and sand drying beds, but it was found inadvisable at present to select any arbitrary standard unit capacities upon which to adjust installation and operating costs for comparison. For this paper it was necessary, therefore, to consider only actual costs even though the unit costs would be changed if some plants were figured as now capable of handling more sludge without additional construction.

The operation data presented represent averages for the past year or two and were utilized in computing the total and unit costs given in the tables. The units of the treatment works upon which the cost figures are based are used in handling the sludge from the time it is deposited in the primary tanks until its disposal on the waste pile. The operation of mechanical sludge collection equipment in primary clarifiers is not included because such equipment is considered essential to the operation of the clarifier.

The fixed charges, represented by interest and depreciation, are calculated at 8 per cent. Unit construction costs at the six plants varied somewhat, though not sufficiently to indicate unbalanced bidding. Digestion tank costs averaged about 60 cents per cubic foot for the mechanical type and about 40 cents per cubic foot for those without mechanical equipment. For open sludge storage tanks they averaged about 20 cents per cubic foot. Sludge bed costs varied from 20 cents to 74 cents per square foot for uncovered beds, but the average for those not requiring special construction was about 30 cents.

Operation costs were more difficult to determine because detailed operating cost records of each plant unit are not ordinarily kept. The estimates were based on judgment and actual experience at each plant and are believed to be reasonably accurate and dependable. Labor and supervision costs were developed from the operating procedure and power and maintenance costs were carefully estimated. The cost of removing dried sludge from the drying beds averaged about 40 cents per yard. Resanding costs for sludge beds varied from $1.00 to $6.00 per thousand square feet per year and reflect the variable loading of the beds. Annual fixed and operating costs are given for each of the plants as total cost, cost per capita, per million gallons of sewage treated and per ton of dry solids to the digestors. Sludge drying comprises about 20 per cent of the total cost as an average of the six plants, the range being from 14 to nearly 35 per cent.

In order to facilitate the comparison of unit costs of the six plants studied with similar figures or estimates for mechanical dewatering, the costs of each plant are given per ton of dry raw solids. These costs vary from $7.15 to $21.50 per ton, averaging $11.23.

Part II. The Economics of Mechanical Sludge Dewatering and Disposal.

By Samuel A. Greeley and C. R. Velzey

In discussing the filtration of sludge there are two general classifications of sludge which may well be considered separately, namely, raw sludge and digested sludge. Filtration is not of itself a complete means of sludge disposal and the methods of final disposal of the filter cake and their cost are a factor in the economics of filtration.

A comparison of sludge disposal costs should include all the items required for final disposal. Some typical procedures are as follows:

A. Digestion
Vacuum Filtration
Dumping of Sludge Cake.
B. Vacuum Filtration of Raw Sludge
Burial of Sludge Cake.
C. Vacuum Filtration of Raw Sludge
Hot Air or Steam Drying
Incineration
Dumping of Residue.

In the computations in this paper, disposal by method *A* is the only one considered. There has not been sufficient experience in the filtration of sludge and the supplementary processes to draw definite conclusions as to costs from available operating data. For this reason the costs given are approximate estimates, based on such data as are available. These estimates do not have general application because variations in the nature of sludge may affect filter rates, amount of chemical required, moisture of the filter cake and other factors. The costs given have been compiled for five different population loads under the following assumptions:

Flow—100 gallons per capita per day,	
Suspended solids in raw sewage	200 p.p.m.,
Removal by primary settling	50 per cent,
Reduction of solids by digestion	40 per cent.

It is also assumed that chemicals will be used for coagulants in doses as follows and that the following filter rates will be obtained:

Type of Sludge	Ferric Chloride per 100 lbs. dry solids	Calcium Oxide per 100 lbs. dry solids	Filter Rate lbs. dry solids per sq. ft. per hr.
Raw Primary	3	12	3
Digested Primary	6	—	5

Based on the above assumptions and with fixed charges taken at 10 per cent the total cost per ton of dry raw solids is estimated to be as follows:

Population	Raw Primary Sludge	Digested Primary Sludge
10,000	$39.30	$20.50
25,000	23.20	11.70
50,000	15.80	7.70
100,000	11.40	5.35
200,000	8.90	4.10

SUMMARY AND CONCLUSIONS

The four authors decided that, based upon their analyses and evaluation of the two methods under discussion, the following summary and general conclusions could be subscribed to by them individually and jointly as their findings:

1. The estimated costs for mechanical filtration of raw or digested sludge, compared to standard digestion and sand drying, indicate that such methods are not economical for plants serving less than 50,000 persons. Further, there is still some doubt concerning plants serving even larger populations.

2. Estimated costs of mechanical filtration of digested sludge are higher than the actual costs of operating sludge drying beds as deter-

mined for six Illinois plants. For the larger plants the two types of dewatering approach equality in cost and it is likely that local conditions, such as lack of area or favorable chemical costs or more efficient use of chemicals, may make mechanical filtration more economical.

3. Cost estimates of mechanical filtration of raw sludge compare quite favorably for plants serving 100,000 persons or more with the combined digestion and sand drying costs found at the six Illinois plants. However, crude sludge cake cannot be readily disposed of because of its character and a complete cost comparison should include further treatment of the sludge by some means such as drying to produce fertilizer or incineration.

4. Further study and experimentation on mechanical dewatering may result in lower costs, but on the other hand, there seems some possibility, with further study, that the net cost of digestion and sand drying may also be further reduced.

5. It must be remembered that in these comparisons actual costs of digestion and sand drying are being compared with only estimated costs of mechanical filtration. When actual installations of mechanical filters to handle crude or digested sludge are in operation at representative plants, much more dependable comparisons can be made.

R. S. Smith

INCREASING THE SALABILITY OF SLUDGE

By P. N. Daniels

Water Works and Sewerage, Vol. 81, No. 8, August, 1934

The sludge discussed in the article is the product of Imhoff or separate sludge digestion tanks that has been air-dried on sand beds to possibly 40 to 50 per cent moisture. This material can be disposed of by use as fill, given away, or, preferably, sold locally as a soil improver.

In many cases it has been found that the sludge cannot be given away. Several reasons may be given for this condition, among them being: poorly digested, odorous sludge; aesthetic objections; lack of knowledge of the value of the humus content; and lack of initiative and salesmanship on the part of the plant operator. An important disadvantage is the condition of the sludge itself. As it comes from the beds it is lumpy and difficult to spread evenly on lawns and gardens and if not thoroughly raked in and pulverized the lumps remain to become soggy and pasty at the first rain.

The elaborate mechanisms such as vacuum filters, driers, and grinders now being installed at large plants are beyond the average plant budget and it is necessary for most operators to devise methods of creating a consumer-demand cheaply and with little or no budget increase.

The first step in preparing the sludge cake for use is to get it into a finely and uniformly divided state so that it may be easily spread or mixed with enriching ingredients if desirable. This may be accomplished by pulverizing or shredding. Lacking a drier, the sludge must be broken up as it comes from the drying beds, in a damp condition. The moisture content of this air-dried sludge makes it practically impossible to handle it in the ordinary type of grinder. Recently, however, a simple device known as the Royer Disintegrator, manufactured by the Royer Foundry and Machine Company of Wilkes-Barre, Pa., which has long been used in foundry work for conditioning caked moulding sand and more recently for mixing compost in agricultural work, has appeared in the sewage field.

This machine consists of a hopper, the bottom of which is a rapidly traveling rubber belt inclined at an angle of 45 degrees. This belt is studded with tooth-like projections which produce a shredding action on the cake beneath which it travels. Hard materials, such as stones, bounce off the teeth and gravitate to the bottom of the hopper to a discharge gate. The shredded sludge cake, lodging in the pockets between the teeth, is thrown out at the upper end of the hopper by centrifugal force. A flexible discharge baffle permits the stream of shredded sludge to be directed to varying elevations.

An extended period of use of such a machine at the Trenton, N. J. sewage treatment plant justifies the following statements: (1) Frozen sludge up to 8 inches in size could be handled satisfactorily. (2) Sludge with as much as 56 per cent moisture failed to clog the machine. (3) The machine would pass sludge at the rate of 1 cu. yd. in 12 minutes, two men being required for shoveling. With hand feed the men could not keep going at this rate and 4 cu. yd. per hour proved to be an average production. (4) The disintegrated sludge averaged 1 to 2 millimeters in diameter. All particles passed the ½ inch screen. (5) The product did not pack, even when exposed to the weather, but it dried very slowly in the interior, probably due to the insulating effect of the dried outer layer.

Sludge produced by such a disintegrating process is much more suitable as a soil conditioner for lawns and gardens than that taken directly from the drying beds. A typical analysis of digested sludge is as follows:

Total nitrogen	1.96 per cent
Ammonia nitrogen	0.12
Available nitrogen	0.76
Total phosphoric acid	0.62
Total potash	0.13

The total plant food constituents in this analysis form only 2.71 per cent of the total bulk, while commercial fertilizezrs run 16 per cent or more. For this reason it is believed inadvisable to sell ordinary digested sludge for anything other than a "soil conditioner," a valuable source of soil humus, comparable with peat moss, compost or rotted manure. Sandy soils are most amenable to treatment with sludge, because the water holding capacity of the ground is increased.

The last step which may be taken to increase the salability of sludge is to fortify it with commercial fertilizers. Sludge alone is not a strong fertilizer and will not give the immediate results obtainable from the use of "Vigoro" and similar soil stimulants. To determine the proper chemicals to add, some knowledge of the different compounds is necessary.

The writer has used the following formula for grass and flowers with considerable success:

Sludge (dry basis)	360 lbs.
Sand (filler)	100 "
Urea (commercial)	1 "
Acid phosphate (16%)	50 "

Potash was not used in this mixture, because the soil did not require it.

Another formula gives the following ingredients:

Dried ground sludge	1650 lbs.
Ammonium sulphate	100 "
Acid phosphate (20%)	200 "
Muriate of potash	50 "

This is a better balanced mixture than the one previously given, as it will be good for almost any crop or average soil. The above will cost about \$6.80 per ton, and as the resulting compound is very much superior to manure at \$10.00 to \$14.00 per ton, there should be no difficulty in selling it at a profit, once the customers are acquainted with its merits.

R. S. Smith

MOST RECENT DEVELOPMENTS IN THE CHEMICAL TREATMENT OF SEWAGE

By M. J. Blew

Public Works, **65,** 10, 12–14 (Oct., 1934)

Chemicals were used extensively in sewage treatment before the general adoption of biological methods, which replaced chemical treatment for a time. More recently, however, interest has been revived in chemical processes, which appear to meet requirements falling between primary and secondary treatment, with a wide range of operation adjustment.

Some 15 chemical processes are now being developed, all involving similar principles but varying in means of accomplishment. They include the use of coagulants, insoluble solids and materials for removing dissolved organic matter from sewage.

Some reported results of operating several different systems of chemical treatment are given as follows:

	Reduction in Per Cent		pH Range
	Suspended Solids	B.O.D.	
Laughlin.			
Dearborn, Mich.	91	68	7.5– 9.1
Coney Island, N. Y.	84	69	9.0–10.3
Guggenheim.			
New York City	95	95	6.0– 8.0
Chicago, Ill.	95	90	———
Lewis.			
Atlanta, Ga.	76	77	10.0–10.8
Stevenson.			
Palo Alto, Calif.	84	60	6.8– 7.4
Streander.			
Philadelphia, Pa.	92–95	75–80	8.0– 8.5
Landreth.			
Winston-Salem, N. C.	87	88	———
Chicago, Ill.	—	66–72	———
Travers.			
Ashland, Ohio	85	50	———
Cabrera.			
Wilmington, Del.	89	78	———

In general, it appears that the known processes involving chemical precipitation will reduce the B.O.D. figure by 60 to 75 per cent. With rapid filtration added, the B.O.D. reduction may be increased to 70–85 per cent. One process (Guggenheim) gives results comparable to activated sludge treatment, but at greater cost of operation.

Total costs of operation have ranged from $8.00 to $20.00 per million gallons, exclusive of fixed charges. Construction costs should range between $50,000 and $100,000 per million gallons daily capacity.

H. W. STREETER

AKRON'S SLUDGE AS A FERTILIZER

ANON.

Public Works, **65**, 10, 14 (Oct., 1934)

Akron, Ohio, has been giving away plain precipitated sludge dried on sand beds. To determine its value for truck garden produce, tests were made in 1931. The results showed that it is of no value for peas, head lettuce, spinach, peppers and cucumbers; of doubtful value for endive and parsley; of moderate value for Kentucky Wonder beans, onions and cabbage; of real value for curled lettuce, squash, pumpkins, turnips and tomatoes, and of exceptional value for lima and stringless beans, parsnips, radishes, cantaloupes, carrots and sweet corn. The sludge contains 2 per cent nitrogen, 0.5 per cent soluble potash and 0.6 per cent available phosphoric acid.

A questionnaire was sent to every treatment plant in the United States where sludge is known to be sold in any form. In 18 of the 48 States, 19 plants report the sale of sludge. Of these, 14 produce sludge similar to Akron's, 3 activated sludge and 2 chemically precipitated sludge. Revenue varies from 25c to $11.00 per ton for sludge similar to Akron's. Total income in 1933 ranges from $55 to $4814. The two chemical plants received $175 and $200.

Under present economic conditions it appears advisable to invest the minimum possible funds in grinding and storage plant and seek cooperation of the press in advancing the use of the city's sludge, as it does have some fertilizer value.

(The above information is given in a bulletin issued by the Akron Department of Public Works, prepared by T. C. Schaetzle, in charge of Sewage Treatment.)

H. W. STREETER

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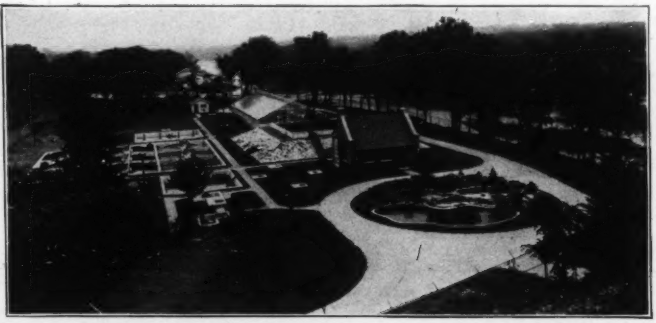

The PFT floating cover used in the square digester lends itself well to the attractive landscaping plan of this modern treatment plant on the bank of the Fox River. Concrete walkways, rip rap on the digester slopes, glass covered sludge beds, etc., as well as the natural beauty of the site, contribute to a pleasing picture. The visitor upon entering the grounds is greeted by a view of the rock garden and pool.

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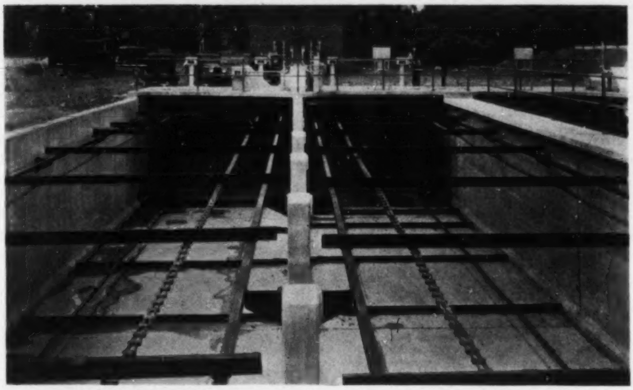

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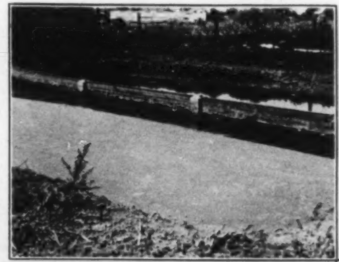

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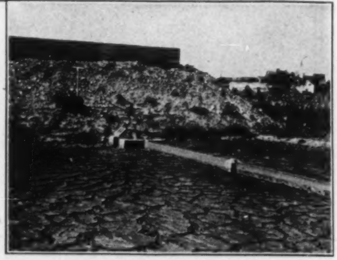

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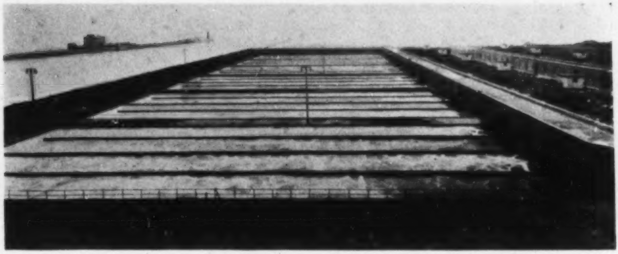


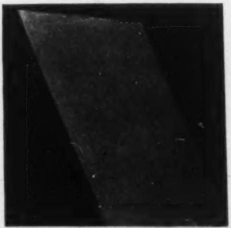
Milwaukee Again Selects Norton Porous Mediums

This Time 13,500 Plates

IN 1927 Milwaukee first used Norton Porous Plates in a number of tanks in their activated sludge sewage disposal plant.

The qualities of these plates—their uniform permeability and their performance for the seven years since installation naturally led to the consideration of Norton Porous Plates for the new addition to the Milwaukee plant. Result: 13,500 more Norton Plates.

If you are constructing or contemplating an activated sludge plant you'll want to specify Norton Porous Plates or Tubes. They are in use the world over—their performance proven by years of service.



NORTON POROUS PLATES

NORTON PRODUCTS—Grinding Machines; Lapping Machines • Grinding Wheels; Abrasives for Polishing; India Oilstones, Pulpstones • Laboratory Ware, Refractories; Porous Plates • Non-slip Tiles and Aggregates

NORTON COMPANY
Worcester, Mass.

R-492

CAST IRON MAINS

Cast iron mains are proof against infiltration—joints are tight and they stay tight. Long life and low maintenance costs are other known advantages of cast iron mains.

Cast iron pipe should be used for any new sanitary lines which will eventually be part of a disposal system. ***For further information write The Cast Iron Pipe Research Association, Thos. F. Wolfe, Research Engineer, 309 Peoples Gas Building, Chicago, Illinois.***

with infiltration-proof joints

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